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A Monograph of Species of Puccinia Occurring on Salvia in North America[1]

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A large majority of the rusts known to occur on *Salvia* in North America are species of *Puccinia.* This paper represents a monographic treatment of these species based mainly on specimens in the Arthur Herbarium. Seventeen North American species of *Puccinia* on *Salvia* are redescribed herein; in addition two new species are described. Other species previously described are reduced to varietal rank, or to synonymy, or are excluded.

Knowledge of this group is based to a large extent on material collected by E. W. D. Holway in Mexico and Central America from the year 1897 until about 1920. The Sydows (13), in 1902, published Latin descriptions of the species known at that time. The only subsequent treatment of the group was that by Arthur (2), using a life-cycle classification.

The geographical distribution of these rusts includes Central America, Mexico, the West Indies, and the United States, with the greatest concentration of species occurring in Guatemala and southern Mexico. In the United States the range extends from Florida northwestward as far as South Dakota, thence southwestward to Mexico, including the plains states and the southern Rocky Mountain area.

MORPHOLOGY AND TAXONOMY

The spermagonia show little variation, being subepidermal, globoid, and paraphysate throughout the group. The aecia are peridiate and typically aecidioid, except in *Puccinia impedita* Mains & Holw., which has uredinoid aecia, and in *P. grata* Arth. & Cumm., which has caeomoid aecia. The uredia are typically pulverulent, while the telia may be pulverulent or more or less compact and pulvinate, the latter type being particularly characteristic of species having caulicolous telia. In the microcyclic species *Puccinia delicatula* (Arth.) Sacc. & Trott. the

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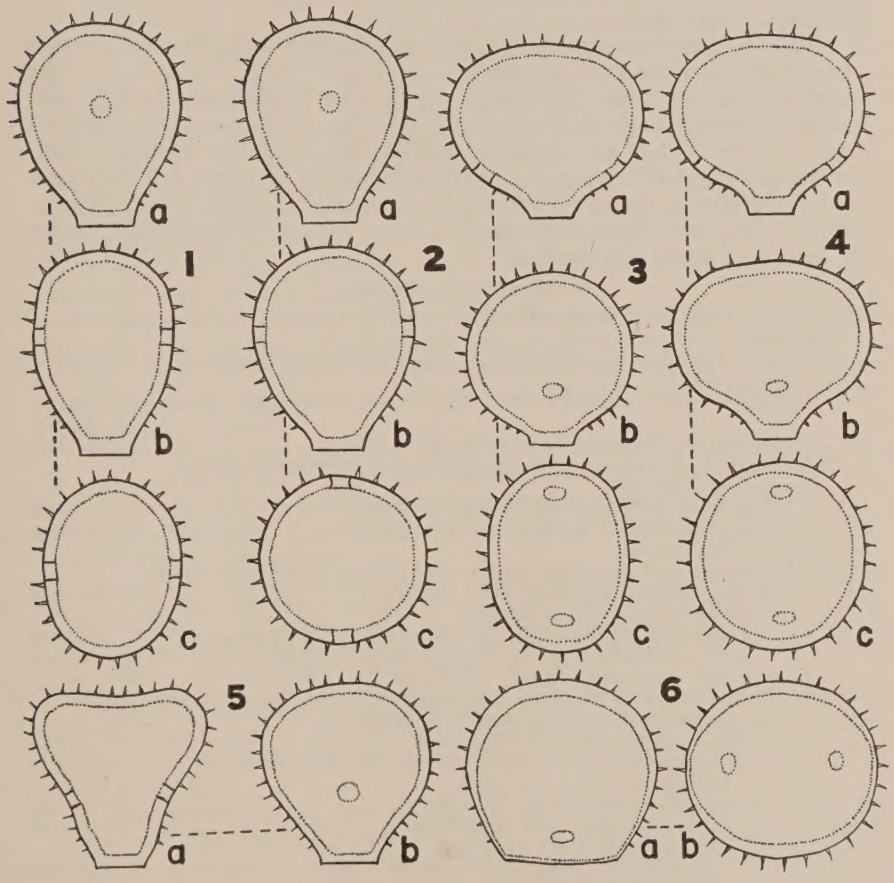
numerous teliospores are tightly packed in the sorus and are separated from one another with difficulty, so that the telium has a firm consistency and forms an indurate, cushion-shaped structure raised considerably above the leaf surface.

The teliospores show little diversity in shape, being ellipsoid or oblong in most species. The pedicel may be fragile or persistent. The wall of the pedicel is generally thin, but in a few species it is considerably thickened. The teliospore wall may be smooth or variously sculptured, with the sculpturing being coarsely verrucose, verruculose, or finely striate. In some species the wall is distinctly laminate throughout, while in others the outer layer is evident only at the apex and at the angles of the septum. In most of these rusts the teliospore wall is thickened over each germ pore to form an umbo with sculpturing like that of the remainder of the wall. The germ pore of the upper cell is usually apical or subapical, while that of the lower cell is next to the septum or occasionally is displaced downward. In the species which commonly have the pedicel attached obliquely or at the septum both germ pores are next to the septum and are covered by a common umbo.

The urediospores exhibit considerable diversity with respect to shape and symmetry. Six types can be recognized on the basis of these differences. Type 1 (Fig. 1, a, b, c) is ellipsoid or obovoid with the pores in surface view, but is much narrower when viewed with the pores in optical section, appearing more nearly oblong. When viewed from below with the hilum in surface view, the asymmetrical nature of the spore becomes apparent. Type 2 (Fig. 2, a, b, c) is ellipsoid or obovoid and symmetrical, so that when viewed from below it is more or less circular. Type 3 (Fig. 3, a, b, c) is asymmetrically oblate-spheroid, thus a flattened-globoid shape when viewed with the pores in optical section but globoid when the pores are in face view. With the hilum in surface view the spore is broadly ellipsoid. Type 4 (Fig. 4, a, b, c,) is oblate-spheroid or globoid and is symmetrical, exhibiting a circular outline when viewed from below. In Type 5 (Fig. 5, a, b) the urediospore has a triangular appearance when the pores are in optical section but is broadly obovoid when the pores are in face view. In this type the pores are located below the equator in slightly concave areas of the wall. In Type 6 (Fig. 6, a, b) the urediospore is more or less globoid, with a flattened base, and the wall is markedly thickened above, but thin in the lower third. Viewed from below, the spore assumes the shape of a broad ellipse, with the wall thickened along the sides and thin at the ends.

The urediospore types most commonly encountered are Types 2 and 4, which tend to intergrade somewhat. In a few species both types, as well as intergrading forms, may be present in the same sorus. In general, however, the urediospores of a given species can be assigned with a fair degree of certainty to a single type. In *P. cuilapensis* Cumm., for example, they are mostly of Type 2. Type 1 is characteristic of *P. vertisepta* Tracy & Gall., and is not found elsewhere in this group. Types 5 and 6 are also confined to one species each.

It is evident that Types 1 and 2 cannot be distinguished when observed with the pores in surface view; spores of Types 3 and 4 likewise may appear identical when viewed with the pores in one plane only. It is necessary to observe the urediospores of these rusts with the pores



FIGS. 1–6. Diagrammatic drawings of the six types of urediospores found in the North American species of *Puccinia* on *Salvia*. 1, a, with the pores in surface view; b, with the pores in optical section; c, with the hilum in surface view. 2, a, with the pores in surface view; b, with the pores in optical section; c, with the hilum in surface view. 3, a, with the pores in optical section; b, with the pores in surface view; c, with the hilum in surface view. 4, a, with the pores in optical section; b, with the pores in surface view; c, with the hilum in surface view. 5, a, with the pores in optical section; b, with the pores in surface view. 6, a, lateral view; b, with the hilum in surface view.

in face view as well as in optical section before satisfactory specific identification can be made.

The urediospore wall is echinulate and is provided with equatorial or subequatorial germ pores. In all but two of the species the urediospores have two or three germ pores, two being the number most frequently encountered.

The classification employed in this paper is based chiefly on teliospore characters, urediospore characters, and life cycle variations. The more useful teliospore characters are (a) the persistence, length, and point of attachment of the pedicel, (b) the thickness of the pedicel wall, (c) the time of germination, and (d) the nature of the spore wall. In the urediospores the number and position of germ pores and the shape and symmetry of the spore are the characters of greatest value. Variations in life cycle have been used to some extent in separating species or groups of species in the key.

KEY TO THE SPECIES

Teliospores typically puccinioid; pedicel usually attached at right angles to septum.
- Telia cinnamon-brown, yellowish, or gray; teliospores germinating without a rest period.
  - Teliospore wall cinnamon- or golden-brown; aecia and uredia present, ... 1. *P. degener*
  - Teliospore wall hyaline; aecia and uredia lacking ..... 2. *P. delicatula*
- Telia blackish brown; teliospores germinating after a rest period.
  - Pedicel thick-walled.
    - Teliospores 18–24 X 29–43 μ; aecia aecidioid ..... 3. *P. caulicola*
    - Teliospores 23–32 X 30–40 μ; aecia uredinoid ..... 4. *P. impedita*
  - Pedicel thin-walled.
    - Teliospore wall minutely verrucose or striate, appearing smooth.
      - Teliospore wall typically 4–6 μ thick ..... 5. *P. salviicola*
      - Teliospore wall 1.5–3 μ thick.
        - Apical umbo prominent; teliospores 20–27 X 31–43 μ ..... 6. *P. grata*
        - Apical umbo lacking; teliospores 14–23 X 23–36 μ .... 7. *P. alamedensis*
    - Teliospore wall conspicuously verrucose.
      - Teliospore wall chestnut- or cinnamon-brown; apical umbo hyaline, yellow or cinnamon, usually conspicuous.
        - Pedicel persistent, 100–140 μ long ..... 8. *P. filiola*
        - Pedicel persistent or semi-persistent, 50–100 μ long.
          - Teliospore wall 4–6 μ thick.
            - Urediospores 20–23 X 23–29 μ ..... 9. *P. gentilis*
            - Urediospores 16–21 X 20–23 μ ..... 10. *P. mitrata*
          - Teliospore wall 2–4 μ thick.
            - Urediospore pores basal next to hilum ..... 11. *P. biporula*
            - Urediospore pores one-half subequatorial to equatorial.
              - Uredia and urediospores cinnamon-brown ..... 12. *P. farinacea*
              - Uredia golden, urediospores pale yellow or hyaline, ... 13. *P. cuilapensis*
        - Pedicel fragile, length of spore or shorter ..... 14. *P. infrequens*
      - Teliospore wall chocolate- or dark chestnut-brown; apical umbo dark brown and inconspicuous, or lacking.
        - Urediospore pores 3 or 4: 2 or 3 equatorial and 1 apical, ... 15. *P. ballotaeflorae*
        - Urediospore pores usually 2, subequatorial.
          - Urediospore wall dark cinnamon and thick above, hyaline and thin below ..... 16. *P. diutina*
          - Urediospore wall uniform, pale cinnamon-brown ..... 17. *P. badia*

Teliospores diorchidioid; pedicel attached in line with septum.
- Teliospores germinating after a rest period; pedical thick-walled, 90–130 μ long ..... 18. *P. vertisepta*
- Teliospores mostly germinating without a rest period; pedicel thin-walled, 30–70 μ long ..... 19. *P. vertiseptoides*

1. PUCCINIA DEGENER Mains & Holw., Arth., in Am. Jour. Bot. **5:** 482. 1918.

Uredo degener Arth., N. Am. Flora **7:** 616. 1924.

Spermagonia amphigenous, in groups, subepidermal, globoid, cinnamon-brown, 90–165 μ in diameter. Aecia amphigenous, aecidioid, in groups up to 2 mm. in diameter; peridial cells ellipsoid or oblong, 21–28 X 29–35 μ in surface view, hyaline or pale yellow, wall 2–4 μ thick, obscurely verrucose; aeciospores broadly ellipsoid or globoid, 16–23 X 20–30 μ, wall 1.5–2.5 μ thick, hyaline or pale yellow, finely verrucose. Uredia hypophyllous, scattered, round, 0.1–0.4 mm. in diameter, pulverulent, cinnamon-brown; urediospores broadly ellipsoid or globoid, 16–23 X 23–27 μ; wall pale cinnamon-brown, 1–1.5 μ thick, moderately to sparsely echinulate, pore 1, ½–¾ subequatorial. Telia hypophyllous, scattered, round, 0.1–0.3 mm. in diameter, pulvinate, cinnamon-brown; teliospores ellipsoid or subclavate, 22–26 X 36–44 μ, rounded at both ends or somewhat narrowed below, moderately constricted at the septum; wall light cinnamon- or golden-brown, 1.5 μ thick, smooth, pore of upper cell apical, of lower near the septum, each covered by a small hyaline papilla 2–3 μ thick, the papilla disappearing at germination, which occurs without a resting period; pedicel hyaline, thin-walled, fragile, usually broken off near the point of attachment, ½ as long as the spore or shorter.

HOSTS AND DISTRIBUTION: *Salvia myriantha* Epling, Guatemala; *S. albiflora* M. & G., Guatemala; *Salvia* sp., Guatemala.

TYPE LOCALITY: Las Nubes, Guatemala, on *Salvia myriantha*.

ILLUSTRATIONS: Cummins, Bull. Torrey Club **70:** Fig. 5; this paper, Fig. 9 (from type).

SPECIMENS EXAMINED:—On *Salvia myriantha:* GUATEMALA: Quezaltenango: Las Nubes, Jan. 16, 1941, *Standley 83614* (type); Volcán de Zunil, Feb. 3, 1941, *Standley 85954*. On *S. albiflora:* GUATEMALA: Quezaltenango, Feb. 4, 1917, *Holway 838* (type of *Uredo degener*). On *Salvia* sp.: GUATEMALA: Río San Ramón, Dept. San Marcos, Feb. 22, 1939, *Standley 66185*.

Puccinia degener is unique among the members of this group because of the single germ pore in the urediospore. The teliospore is also distinctive, having a smooth, light brown wall with a small papilla over each germ pore.

The urediospores in this species are of Type 2. All spore forms are present in the type specimen, although the aecia are too old to permit accurate description, particularly with respect to the peridial cells.

P. degener is not closely approached by any other North American *Salvia* rust. In addition to the distinctive characteristics mentioned above it differs from most eu-forms on *Salvia* in having teliospores which germinate without a resting period. In this respect it resembles the South American species, *Puccinia albicera* Jacks. & Holw., to which it is probably closely related.

2. PUCCINIA DELICATULA (Arth.) Sacc. & Trott., in Sacc. Syll. Fung. **21:** 657. 1912.

Polioma delicatula Arth., Jour. Mycol. **13:** 29. 1907.
Micropuccinia delicatula Arth. & Jacks., N. Am. Flora **7:** 561. 1922.

Spermagonia unknown, probably lacking. Aecia and uredia lacking. Telia amphigenous, chiefly hypophyllous, scattered, round, 0.3–0.5 mm.

in diameter or confluent in groups up to 2 mm. across, pulvinate, compact, pale yellow or dirty white; teliospores fusiform or narrowly ellipsoid, (10–) 12–16 X (26–) 30–46 (–50) μ, narrowed at both ends, slightly constricted at the septum, germinating without a resting period; wall hyaline, usually uniformly 1–1.5 μ thick, slightly thickened apically and at the septum in some specimens, pedicel hyaline, thin-walled, semi-persistent, usually broken away, 3–4 μ wide, up to 50 μ long.

HOSTS AND DISTRIBUTION: *Salvia albo-coerulea* Lindl., Mexico; *S. cinnabarina* M. & G., Guatemala, Mexico; *S. elegans* Vahl, Guatemala, Mexico; *S. grandis* Epling, Guatemala; *S. holwayi* Blake, Guatemala; *S. karwinskii* Benth., Honduras; *S. pulchella* DC., Guatemala.

TYPE LOCALITY: Amecameca, Mexico, on *Salvia elegans*.

ILLUSTRATIONS: Fig. 7 (from type).

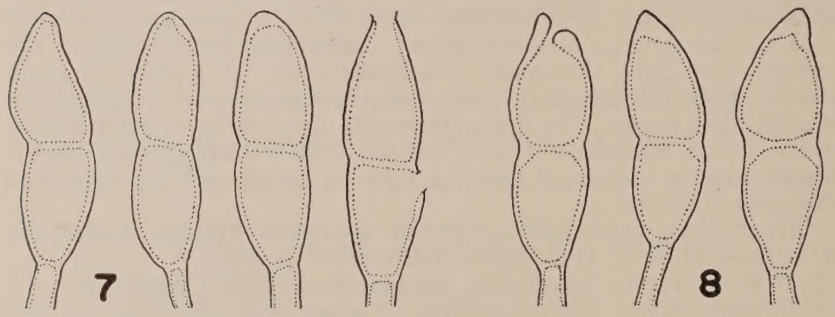


FIG. 7. Teliospores of *Puccinia delicatula*. (From type.) x 800. FIG. 8. Teliospores of *P. delicatula* var. *niveoides*. Note the marked thickening of the wall at the septum and apex. (From type.) x 800.

SPECIMENS EXAMINED:—On *Salvia albo-coerulea:* MEXICO: Cumbre, Dist. Temascaltepec, Mar. 21, 1933, *Hinton 3510*. On *S. cinnabarina:* GUATEMALA: Huehuetenango, Jan. 23, 1917, *Holway*; San Andrés Sematabj, Dept. Solola, Jan. 15, 1939, *Standley 62747, 62755;* Quezaltenango, Jan. 18, 31, 1917, *Holway;* Alameda, Nov. 2, 1936, *Johnston 239;* Sacapulas, Jan. 10–15, 1939, *Johnston 1448;* Serchil, Jan. 30, 1941, *Standley 85364;* Finca La Alameda, Dept. Chimaltenango, Dec. 11–22, 1940, *Standley 79960;* MEXICO: Toro Muerto, Dist. Mina, Dec. 18, 1937, *Hinton 11091*. On *S. elegans:* GUATEMALA: Solola, Jan. 28, 1915, *Holway;* MEXICO: Amecameca, Oct. 20, 1903, *Holway 5200* (type); Desierto de los Leones, April 13, 1948, *Vallejo 727*. On *S. grandis:* GUATEMALA: Dept. Zacapa, Oct. 12, 1939, *Steyermark 29799*. On *S. holwayi:* GUATEMALA: Zunil, Jan. 28, 1917, *Holway*, Quezaltenango, Jan. 18, 1917, *Holway*. On *S. karwinskii:* HONDURAS: Siquatepeque, Mar. 25–Apr. 5, 1947, *Standley & Chacon 6269*. On *S. pulchella:* GUATEMALA: San Rafael, Dept. Guatemala, Jan. 9, 1915, *Holway*.

Among the species treated in this monograph *Puccinia delicatula* is distinct as to life cycle, being a lepto-form and apparently lacking spermagonia. It is the only member of the group having hyaline teliospores.

Previously the teliospores of this species have been described as having uniform walls. During the preparation of this paper, however, a specimen on *Salvia grandis* was obtained in which the teliospores show some thickening at the apex as well as at the septum angles. This affects the status of *P. niveoides*, a species described by Cummins (6)

as new because of the marked apical and septal thickening. In view of the intermediate nature of the teliospores of *P. delicatula* on *Salvia grandis* it seems advisable to reduce *P. niveoides* to varietal rank within *P. delicatula* to include forms of the latter which exhibit a pronounced thickening of the teliospore wall.

PUCCINIA DELICATULA (Arth.) Sacc. & Trott. var.
niveoides (Cumm.) Baxter stat. nov.

Puccinia niveoides Cumm., Bull. Torrey Club **67**: 611. 1940.

A forma typica speciei differt teliosporae lenissime majores; membrana ad apicem et septum usque ad 3.5 μ incrassata.

HOSTA AND DISTRIBUTION: *Salvia cinnabarina* M. & G., Guatemala.

TYPE LOCALITY: San Juan Sacatepéquez, Guatemala, on *Salvia cinnabarina*.

ILLUSTRATIONS: Fig. 8 (from type).

SPECIMENS EXAMINED:—On *Salvia cinnabarina:* GUATEMALA: Volcán de Agua, Nov. 12, 1936, *Johnston 218;* San Juan Sacatepéquez, Dec. 8, 1938, *Standley 59243* (type).

The pronounced thickening of the teliospore wall typifies this variety.

3. PUCCINIA CAULICOLA Tracy & Gall., in Jour. Mycol. **4**: 20. 1888.

Puccinia nigrescens Peck, Bot. Gaz. **3**: 35. 1878. Not *P. nigrescens* Kirch. 1856.
Dicaeoma salviae Kuntze, Rev. Gen. **3**^{3}: 467. 1898.
Dicaeoma caulicola Kuntze, Rev. Gen. **3**^{3}: 468. 1898.
Dicaeoma nigrescens Kuntze, Rev. Gen. **3**^{3}: 469. 1898.
Puccinia salviae-lanceolatae Bubák, in Syd. Monogr. Ured. **1**: 294. 1902.

Spermagonia amphigenous, in groups accompanying or opposite the aecia, subepidermal, globoid, cinnamon-brown, 80–125 μ in diameter. Aecia chiefly hypophyllous, in clusters on brown spots 3–10 mm. across, aecial groups up to 3 mm. in diameter, frequently becoming confluent and covering most of the leaf surface; peridial cells rhomboidal, ellipsoid or oblong, 16–23 X 20–43 μ in surface view, hyaline, outer wall 3–5 μ thick, obscurely striate, appearing smooth, inner wall 2–3 μ thick, finely verrucose; aeciospores angularly globoid, ellipsoid or rhomboidal, 12–21 X 20–30 μ; wall pale yellow or hyaline, 1–2 μ thick, closely and finely verrucose. Uredia amphigenous, scattered, round, 0.3–0.6 mm. in diameter, pulverulent, cinnamon-brown; urediospores oblate-spheroid, 19–24 μ broad by (13–) 16–20 (–22) μ high; wall pale cinnamon-brown, 1–1.5 μ thick, moderately and finely echinulate, pores 2, occasionally 3, ½ subequatorial. Telia amphigenous and caulicolous, scattered or occasionally confluent, roundish and 0.2–0.5 mm. in diameter on leaves, elliptic or lenticular and 1–3 mm. in length or confluent in groups up to 12 mm. long on stems, pulvinate, more or less compact, becoming pulverulent, blackish brown; teliospores oblong or narrowly ellipsoid, (16–) 18–24 (–27) X (26–) 29–43 (–48) μ, rounded apically, somewhat narrowed and obtuse or occasionally rounded below, slightly constricted at the septum; wall chestnut-brown, 2–3 μ thick, finely and obscurely verrucose, appearing smooth; pore of upper cell apical, of lower next to the septum, each capped by a brown or yellowish umbo 3–4 μ thick; pedicel faintly tinted, thick-walled, persistent, straight or slightly curved, tapering gradually downward, 80–100 μ long on leaves, up to 170 μ long on stems.

HOSTS AND DISTRIBUTION: *Salvia greggii* A. Gray, U.S.A.; *Salvia lanceolata* Willd. (*Salvia lanceifolia* Poir.), U.S.A., Mexico.

TYPE LOCALITY: Canyon City, Colo., U.S.A., on *Salvia lanceolata*.

ILLUSTRATIONS: Sydow, Monogr. Ured. I: Tab. XIX, Fig. 276; Sydow, Monogr. Ured. I: Tab. XX, Fig. 280 (as *P. salviae-lanceolatae* Bubák); Arthur, Manual of Rusts, Fig. 409; this paper, Fig. 10 (from type).

EXSICCATI: Ell. & Ev. Fungi Columb. 1848, 1849, 1185, 1071 (as *P. nigrescens* Peck); Barth. N. Am. Ured. 1534, 27, 536, 627, 335, 3338, 1535; Clem. Crypt. Form. Colo. 552; Syd. Ured. 1815, 1075 (as *P. nigrescens* Peck); Kell. & Sw. Kans. Fungi 43 (as *P. nigrescens* Peck); Griff. W. Am. Fungi 275, (as *P. nigrescens* Peck); Ell. N. Am. Fungi 1458, 1459 (as *P. nigrescens* Peck).

SPECIMENS EXAMINED:—*On Salvia greggii:* U.S.A.: Texas: San Antonio, May 17, 1941, *Mauldin*. On *S. lanceolata:* U.S.A.: Kansas: Stockton, July 9, 1903, *Bartholomew*, March 13, 1930, *Bartholomew*; Rockport, March 13, 1903, *Bartholomew 3005*, March 18, 1903, *Bartholomew;* Miami Co., July, 1883, *Oyster;* Manhattan, June 2, 1916, *Jackson, Melchers & Arthur*, Aug., 1884, Sept., 1884, *Kellerman;* Rooks Co., May 10, 1896, Oct., 1896, March 13, 1903, *Bartholomew*. Colorado: Canyon City, Aug. 21, 1887, *Tracy & Evans 769* (type); Momson, Oct. 1896, *Bethel;* Denver, Sept., 1911, *Bethel;* Vernon, Aug. 7, 1907, *Clements;* Salida, July 2, 1921, *Bethel;* Leyden, March 26, 1910, *Bethel;* Boulder, March 14, 1908, *Bethel;* Rocky Ford, Sept. 5, 1911, *Kern 2701;* Colorado City, Aug., 1906, *Shantz*. New Mexico: Hot Springs, Sept. 18, 1896, *Holway;* Tejano Exp. St., Sept. 19, 1916, *Long & Seay;* Rio Penasco, Jan. 25, 1922, *Earle;* Bernalillo, July 23, 1908, *Hedgcock 1514*. Nebraska: Red Cloud, Oct. 6, 1910, Aug. 4, 1911, *Bates;* Lincoln, Oct. 3, 1903, *Shantz*. South Dakota: Running Water, Sept. 10, 1892, *Thornber 159;* Rapid City, Aug., 1887, *Griffiths & Carter;* Ft. Pierre, Aug. 23, 1883, *Holzinger;* Spearfish, July 28, 1922, *Bartholomew*. Iowa: Indianola, Sept. 24, 1895, *Carver*. Texas: Big Springs, Oct. 13, 1902, *Tracy 8272*. Missouri: St. Joseph, July 3, 1936, *Tucker*. MEXICO: Pachuca, Oct. 5, 1899, *Holway 3583;* Tula, Sept. 20, 1898, *Holway 3201*.

Puccinia caulicola is the most commonly collected *Salvia* rust within the borders of the United States, occurring almost exclusively on *Salvia lanceolata*. It is closely related to *P. impedita*, a more southern form which has broader, thicker-walled teliospores. The teliospores of both species have characteristic thick-walled, tinted pedicels which are not flexuous or bent. Arthur (4) was in error in describing the pedicels as "delicate." In both *P. caulicola* and *P. impedita* the pedicels are persistent, stout, and longer than is usual in this group, this being particularly noticeable in the caulicolous telia. *P. caulicola* can be differentiated from *P. impedita* chiefly by the narrower, thinner-walled teliospores. There is a marked difference in the aecia, those of *P. caulicola* being aecidioid, while in *P. impedita* they are uredinoid. *P. caulicola* also resembles a European species, *P. nigrescens* Kirch., but differs in having Type 4 urediospores with subequatorial pores and teliospores with persistent, thick-walled pedicels.

Greenhouse cultures of this species were made in 1903 by Kellerman (11) and by Arthur (1). Teliospores from sori on *Salvia lanceolata* were applied to the same host, resulting in the production of spermagonia and aecia. In 1921, Bethel made an open-air culture of *P. caulicola*, using aeciospores and obtaining uredia. The data from Bethel's culture are in the Arthur Herbarium but were not published.

4. PUCCINIA IMPEDITA Mains & Holw., Arth., in Mycologia **10:** 135. 1918.

Uredo salviarum Mayor, Mem. Soc. Neuch. Sci. Nat. **5:** 592. 1913.
Bullaria impedita Arth. & Mains, N. Am. Flora **7:** 493. 1922.

Spermagonia epiphyllous, in groups, subepidermal, flattened globoid, cinnamon-brown, 80–165 μ in diameter. Aecia amphigenous, chiefly

FIG. 9. Teliospore of *Puccinia degener*. (From type.) x 800. FIG. 10. Teliospores of *P. caulicola*. (From type.) x 800. FIG. 11. Teliospores of *P. impedita*. (From type.) x 800. FIG. 12. Teliospores of *P. salviicola*. (From type.) x 800. FIG. 13. Teliospores of *P. grata*. (From type.) x 800.

epiphyllous, uredinoid, lacking a peridium; aeciospores globoid, obovoid or broadly ellipsoid, 20–23 X 23–28 μ, wall dark cinnamon-brown, 1.5–2 μ thick, rather sparsely and prominently echinulate, pores 2, occasionally 3, ¼ subequatorial. Uredia amphigenous, chiefly hypophyllous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores globoid or obovoid, 15–23 X 17–24 μ, or

oblate-spheroid, 18–23 μ broad by 16–20 μ high; wall light cinnamon-brown, 1–1.5 μ thick, moderately and finely echinulate, pores 2, occasionally 3, varying from approximately equatorial to ½ subequatorial. Telia caulicolous, occasionally also hypophyllous, scattered, pulvinate, more or less compact, blackish brown, round and 0.2–0.5 mm. in diameter on leaves, broadly elliptical or lenticular and 2–10 mm. long on stems; teliospores oblong or broadly ellipsoid, 23–32 X 30–40 (–45) μ, rounded or obtuse above and below, not constricted at the septum; wall dark chestnut-brown, 3–5 μ thick, irregularly and obscurely verrucose, appearing smooth below, pore of upper cell apical or subapical, of lower next to the septum, each covered by a brownish umbo 3–5 μ thick; pedicel hyaline, with a pale brown tint next to the spore, thick-walled, persistent, straight or slightly curved, tapering downward, 100–150 μ long on leaves, up to 170 μ, rarely 180 μ on stems.

HOSTS AND DISTRIBUTION: *Salvia coccinea* Juss., Puerto Rico; *S. hispanica* L., Mexico, Guatemala; *S. hyptoides* M. & G., El Salvador, Honduras, Costa Rica; *S. occidentalis* Sw., Puerto Rico, St. Croix, St. Thomas, Jamaica, Cuba, Santo Domingo, El Salvador, Costa Rica, Guatemala; *S. rubiginosa* Benth., El Salvador; *S. tiliaefolia* Vahl, Costa Rica, Mexico, Guatemala; *Salvia* sp., Mexico, Honduras.

TYPE LOCALITY: San Jose, Costa Rica, on *Salvia hyptoides*.

ILLUSTRATIONS: Fig. 11 (from type).

EXSICCATI: Syd. Fungi Exot. Exsicc. 576.

SPECIMENS EXAMINED:—On *Salvia coccinea:* PUERTO RICO: Maricao, March 24, 1916, *Whetzel & Olive 128*, July 8, 1924, *Whetzel, Kern & Toro 2412;* Mayagüez, March 3, 1916, *Whetzel & Olive 129;* Yauco-Lares Road, Jan. 24–April 5, 1923, *Seaver & Chardon 1628*, June 16, 1924, *Whetzel, Kern & Toro 2200;* El Gigante, July 16, 1915, *Stevens 8530;* Lapica, Jan. 24–April 5, 1923, *Seaver & Chardon 1557;* Rio Prieto, June 20, 1924, *Whetzel, Kern & Toro 2279;* Finca Limon Villalba, July 14, 1924, *Whetzel, Kern & Toro 2220*. On *S. hispanica:* MEXICO: Jacala, Hidalgo, Nov. 17, 1937, *Kenoyer 628;* Uruapan, Michoacan, Oct. 31, 1905, *Pringle 10155;* Reyes, Oaxaca, Oct. 20, 1894, *Nelson 1782;* GUATEMALA: Dept. Huehuetenango: Chiantla, Feb. 18, 1939, *Standley 65629;* Aquacatán, Dec. 27, 1940, *Standley 81197*. On *S. hyptoides:* EL SALVADOR: San Salvador, 1921, *Calderon 182*, Dec. 20, 1921, *Standley 19542;* HONDURAS: Dept. Morazán: Agua Amarilla, Nov. 22–30, 1946, *Standley & Williams 424;* El Zamorano, Feb. 17–March 8, 1947, *Standley 3834;* COSTA RICA: San José, Dec. 26, 1915, *Holway 297* (type); Orotina, Dec. 31, 1915, *Holway 340;* Heredia, Dec. 17, 1915, *Holway 264*. On *S. occidentalis:* PUERTO RICO: Yauco, March 30, 1916, *Whetzel & Olive 133;* Mayagüez, Jan. 15, 1913, *Stevens 285*, April 17, 1913, *Stevens 526*, March 7, 1916, *Whetzel & Olive 131*, March 20, 1916, *Whetzel & Olive 130*, Jan., 1923, *Seaver & Chardon 1684*, Jan. 24, 1923, *Seaver & Chardon 1709;* Río Prieto, June 20, 30, 1924, *Whetzel, Kern & Toro 2203, 2204;* Maricao, March 3, 1916, *Whetzel & Olive 132;* Coazoal, Feb. 21, 1913, *Stevens 407;* Palo Seco, Feb. 3, 1916, *Stevenson 3844;* Caguas, 1899, *Heller 941;* La Carmelita, April 19, 1904, *Clinton 109;* Ponce, Feb., 1911, *Holway 7;* Mt. Fajardo, July 1, 1924, *Whetzel, Kern & Toro 2468;* Aguada, Nov. 22, 1913, *Stevens 5088;* Ciales Rd., June 20, 1924, *Whetzel, Kern & Toro 2269;* Lapica, Jan. 24, 1923, *Seaver & Chardon 1515;* Cieba, June 30, 1924, *Whetzel, Kern & Toro 2458;* Rio Prieto, June 20, 1924, *Whetzel, Kern & Toro 2204;* Vieques, July 17, 1924, *Whetzel, Kern & Toro 2113;* Mts. Yabocoa, July 2, 1924, *Whetzel, Kern & Toro 2452;* Quebradillas, June 21, 1924, *Whetzel, Kern & Toro 2268;* Yauco-Lares Rd., Jan. 24, 1923, *Seaver & Chardon 1607;* ST. CROIX: Bassin, Jan. 17, 1896, *Rickseeker 10;* March 18–25, 1923, *Seaver 918;* ST. THOMAS: Mar. 10–17, 1923, *Seaver 762;* JAMAICA: Port Antonio, Feb. 18, 1915, *Holway 220;* Mt. Diabolo, April, 1903, *Underwood 1892;* CUBA: San Pedro, Feb. 12–March 22, 1916, *Britton & Wilson 14270;* Marianao, Feb. 6, 1916, *Johnston 442;* Cebollas, March 24, 1916, *Johnston 524;* Herredura, Jan. 1, 1918; *Earle 838;* Sabanilla, May 22, 1916, *Johnston 593;* SANTO DOMINGO: San Cristobal, March 13, 1926, *Kern & Toro 48;* EL SALVADOR: Ahuachapán, Jan. 9–27, 1922, *Standley 19741*,

Jan. 16–25, 1947, *Standley & Padilla 2762;* COSTA RICA: Orotina, Dec. 30, 1915, *Holway 326;* GUATEMALA: San Felipe, Retalhuleu, Jan. 13, 1917, *Holway 712;* Antigua, Dec. 27, 1916, *Holway 642;* Cuilapilla, Dept. Santa Rosa, Nov. 23, 1940, *Standley 78074.* On *S. rubiginosa:* EL SALVADOR: San Salvador, Dec. 20, 1921–Jan. 4, 1922, *Standley 19588.* On *S. tiliaefolia:* COSTA RICA: La Caja, San José, Dec. 21, 1924, *Sydow;* Tres Ríos, Jan. 17, 1916, *Holway 441;* MEXICO: Guadalajara, Jalisco, Sept. 16, 1899, *Holway 3434;* Cuernavaca, Morelos, Oct. 1, 1899, *Holway 3550;* GUATEMALA: Dept. Jalapa: Jalapa, Nov. 7–18, 1940, *Standley 76494, 77419;* Dept. Sacatepéquez: Antigua, Nov., 1938–Feb., 1939, *Standley 61714, 64286;* Dept. Quezaltenango: Río Samalá, Jan. 18, 1941, *Standley 83938;* Zunil, Jan. 13, 1941; *Standley 83200;* Santa María de Jesús, Jan. 25, 1941, *Standley 84640;* Dept. Chimaltenango: Finca La Alameda, Dec. 11–22, 1940, *Standley 79755.* On *Salvia* sp.: MEXICO: Cuernavaca, Morelos, Oct. 1, 1899, *Holway 3550;* HONDURAS: El Achote, Dept. Comayagua, Feb. 28, 1928, *Standley 5611.*

Puccinia impedita differs from *P. caulicola* chiefly in having uredinoid aecia and in having teliospores which are broader and more nearly ellipsoid. The urediospores are mostly of Type 4.

The collections on *Salvia coccinea* bearing uredinoid aecia were assigned to *P. impedita* by Arthur (*l.c.*) on the basis of the identity of the host and the similarity of the aeciospores to the urediospores of this species. According to Arthur, no teliospores were present to definitely establish the connection. During the present study, however, a single telium was found on one of these aecial specimens, Seaver and Chardon No. 1628 from Puerto Rico.

The geographical distribution of *P. impedita* comprises the West Indies, Central America, and southern Mexico. This species has been reported also from South America. It is the only *Salvia* rust known to occur in the West Indies, where it is widely distributed.

5. PUCCINIA SALVIICOLA Diet. & Holw., Holw., in Bot. Gaz. **34:** 33. 1897.

Dicaeoma salviicola Arth., N. Am. Flora **7:** 411. 1921.

Spermagonia epiphyllous, in groups, subepidermal, globoid, chestnut-brown, 99–130 μ in diameter. Aecia hypophyllous, aecidioid, in widely scattered groups up to 2 mm. in diameter; peridial cells rhomboidal, 16–23 X 33–40 μ in surface view, pale yellow or hyaline, outer wall 3–6 μ thick, smooth, inner wall 2–3 μ thick, finely verrucose; aeciospores ellipsoid or obovoid, 14–22 X 24–34 μ; wall light cinnamon-brown, 1–2.5 μ thick, finely and closely verrucose. Uredia amphigenous, scattered, roundish, 0.2–0.4 mm. in diameter, pulverulent, cinnamon-brown; urediospores broadly ellipsoid or obovoid, (16–) 18–23 (–26) X 19–30 μ; wall cinnamon-brown, 1–1.5 μ thick, moderately and prominently echinulate, pores 2, equatorial. Telia amphigenous, scattered, round, 0.2–1 mm. in diameter, pulverulent or occasionally more or less compact, blackish brown; teliospores broadly ellipsoid, (23–) 26–32 X (29–) 33–46 μ, rounded at both ends, slightly or not constricted at the septum; wall chestnut-brown, 4–6 μ thick, 3 μ thick in some specimens, minutely verrucose-striate, appearing smooth; pore of upper cell apical or subapical, surmounted by a brownish or hyaline umbo up to 4 μ thick, pore of lower cell next to the septum, with a hyaline or yellowish umbo about 3 μ thick; pedicel hyaline, thin-walled, persistent, with an inconspicuous brownish collar at the point of attachment, tapering rather sharply downward, somewhat flexuous or nearly straight, up to 90 μ in length.

HOSTS AND DISTRIBUTION: *Salvia assurgens* H.B.K., Mexico; *S. cardinalis* Kunth., Mexico; *S. coccinea* Juss., U.S.A., Mexico; *S. forreri* Greene, Mexico; *S. hypoglauca* Briq., Mexico; *S. occidentalis* Sw., Guatemala; *S. prunelloides* H.B.K., Mexico; *S. riparia* Kunth., Guatemala, Mexico; *Salvia* sp., Mexico.

TYPE LOCALITY: Near City of Mexico, D.F., Mexico, on *Salvia prunelloides*.

ILLUSTRATIONS: Sydow, Monogr. Ured. **1:** Tab. XX, Fig. 278; this paper, Fig. 12 (from type).

EXSICCATI: Barth. N. Am. Ured. 59, 1469.

SPECIMENS EXAMINED:—On *Salvia assurgens:* MEXICO: Patzcuaro, Michoacan, Oct. 20, 1898, *Holway 3184*. On *S. cardinalis:* MEXICO: Desierto de los Leones, Nov. 1, 1937, *Kenoyer 468*. On *S. coccinea:* U.S.A.: Austin, Texas, Oct. 28, 1908, *Heald & Wolf 349;* St. Augustin, Fla., March 26, 1903, *Holway;* MEXICO: Victoria, Tamaulipas, Feb. 1 to April 9, 1907, *Palmer 77*. On *S. forreri:* MEXICO: Mt. Orizaba, Veracruz, 1938, *Balls 5339*. On *S. hypoglauca:* MEXICO: Pachuca, Hidalgo, Oct. 5, 1899, *Holway 3576*. On *S. occidentalis:* GUATEMALA: Antigua, Dept. Sacatepéquez, Nov., 1938–Feb., 1939, *Standley 63043*. On *S. prunelloides:* MEXICO: Near City of Mexico, Sept. 26, 1896, *Holway* (type); Mt. Nevada de Toluca, Oct. 15, 1903, *Holway 5157*. On *S. riparia:* GUATEMALA: Finca La Alameda, Dept. Chimaltenango, Dec. 11–22, 1940, *Standley 79739;* MEXICO: Canasayal, Campeche, Dec. 12, 1900, *Goldman 459*. On *Salvia* sp.: MEXICO: Rio Hondo, near City Mex., Sept. 30, 1900, *Holway;* El Riego, Puebla, Sept. 8, 1905, *Rose 10163*.

This species is rather widely distributed, occurring in the southern United States, Mexico, and Guatemala.

P. salviicola is characterized by having broadly ellipsoid teliospores with thick, nearly smooth walls, and collared, sharply tapering pedicels. The urediospores are chiefly of Type 2. In a few specimens the teliospores have walls much thinner than those in the type specimen and show some resemblance to those of *P. impedita*. This is particularly true of the collections from Mexico on *Salvia assurgens* and of Holway's specimen from Florida on *S. coccinea*. Upon close examination, however, it becomes apparent that considerable differences exist between these telial specimens of *P. salviicola* and those of *P. impedita*. The chief difference is in the pedicel, which is thick-walled, slightly tinted, and 100–170 μ long in *P. impedita*, while in *P. salviicola* it is thin-walled, hyaline and shorter. Moreover, the teliospore wall in *P. impedita* is darker and is more conspicuously verrucose at the apex.

6. PUCCINIA GRATA Arth. & Cumm., in Ann. Mycol. **31:** 42. 1933.

Spermagonia amphigenous, in groups, subepidermal, flattened globoid, cinnamon-brown, 130–200 μ in diameter. Aecia amphigenous, caeomoid, in groups up to 2 mm. in diameter, peridium lacking; aeciospores obovoid or ellipsoid, 16–23 X 23–32 μ; wall hyaline, 1.5–3 μ thick, rather coarsely verrucose, the tubercles deciduous in part. Uredia unknown, probably lacking. Telia hypophyllous, sparsely scattered, round, 0.1–0.5 mm. in diameter, pulvinate, compact, blackish brown; teliospores broadly ellipsoid, 20–27 X 31–43 μ, rounded at both ends, not constricted at the septum; wall light chestnut-brown, 1.5–2.5 μ thick at the base and sides, thickened to 3–4 μ at the angles of the septum, minutely verrucose-striate, appearing smooth, pore of upper cell apical, capped by a broad, hyaline or yellowish umbo which is conspicuously striate and 4–6 μ thick, pore of lower cell near the septum, capped

by a hyaline wall thickening, occasionally umbonate, pedicel hyaline, thin-walled, fragile, frequently broken away at the point of attachment, 30–40 μ long.

HOSTS AND DISTRIBUTION: *Salvia concolor* Lamb (*S. cyanea* Benth.), Mexico.

TYPE LOCALITY: El Desierto, D.F., Mexico, on *Salvia concolor*.

ILLUSTRATIONS: Arthur & Cummins, Ann. Mycol. **31:** 43, Fig. C; this paper, Fig. 13 (from type).

SPECIMENS EXAMINED:—On *Salvia concolor:* MEXICO: El Desierto, D. F., Oct. 13, 1923, *Smyth 199;* Oct. 6, 1930, *D. Reddick 6* (type); July 8, 1932, *Plunkett 25*.

Puccinia grata is not closely approached by any other member of this group. It is readily distinguished because of the caeomoid aecia, the coarsely verrucose aeciospores, and the light brown, nearly smooth teliospores with fragile pedicels. The teliospore wall is characteristically thickened and paler at the angles of the septum; at the apex it forms a conspicuous striate umbo. Uredia have not been found and probably are not formed.

7. **Puccinia alamedensis** Baxter sp. nov.

Spermagoniis, aeciis et urediis adhuc ignotis. Teliis hypophyllis, sparsis vel aggregatis, rotundatis, 0.3–1.0 (–1.5) mm. diam., pulvinatis, densis, atro-brunneis; teliosporae ellipsoideae vel subclavatae, 14–23 X 23–36 μ, ad apicem rotundatae, ad basim rotundatae vel attenuatae, medio leniter vel non constrictae; membrana pallide castaneo-brunnea, 1.5–2.5 (–3) μ cr., ad apicem subinde usque ad 4 μ incrassata, inconspicue et minuteque verrucosa, manifeste levis; poro superiore apicali, inferiore juxta septum sito; pedicello hyalino, persistenti, 3–5 μ lato, deorsum attenuato, 30–50 (–70) μ longo.

On leaves of *Salvia tiliaefolia*, in Guatemala.

Spermagonia, aecia and uredia unknown. Telia hypophyllous, scattered or in groups, round, 0.3–1.0 (–1.5) mm. in diameter, pulvinate, compact, blackish brown; teliospores ellipsoid or subclavate, 14–23 X 23–36 μ, rounded at the apex, rounded or somewhat narrowed at the base, slightly or not constricted at the septum; wall light chestnut-brown, 1.5–2.5 (–3) μ, occasionally thickened to 4 μ at the apex, obscurely and minutely verruculose, appearing smooth; pore of upper cell apical, of lower next to the septum, neither provided with an umbo; pedicel hyaline with a yellowish tint next to the spore, thin-walled, persistent, narrow, 3–5 μ in width at the point of attachment, 30–50 μ in length, occasionally up to 70 μ long.

HOSTS AND DISTRIBUTION: *Salvia tiliaefolia* Vahl, Guatemala.

TYPE LOCALITY: Alameda, Guatemala, on *Salvia tiliaefolia*.

ILLUSTRATIONS: Fig. 14 (from type).

SPECIMENS EXAMINED:—On *Salvia tiliafolia:* GUATEMALA: Alameda, Nov. 15, 1936, *Johnston 322* (type).

This species, of which only the telial stage is known, is based on a specimen obtained from the herbarium of the Chicago Natural History Museum. The teliospores are readily distinguishable from those of other North American *Salvia* rusts, being considerably smaller and having uniformly thin walls which are not markedly thickened over

the pores. The extremely fine, verruculose sculpturing of the walls makes them appear smooth.

Apparently the nearest relative of *P. alamedensis* is the European species *P. nigrescens*, from which it differs chiefly in the size of the teliospores and in lacking the conspicuous apical umbo typical of the latter species.

8. PUCCINIA FILIOLA Mains & Holw., Arth., in Am. Jour. Bot. **5:** 482. 1918.

Dicaeoma filiolum Arth., N. Am. Flora **7:** 415. 1921.

Spermagonia and aecia unknown. Uredia hypophyllous, scattered, round, small, 0.1–0.2 mm. in diameter, pulverulent, cinnamon-brown; urediospores triangular-obovoid, 20–23 X 23–28 μ; wall cinnamon-brown, 1.5–2 μ thick, moderately echinulate, pores 2, ½ subequatorial. Telia hypophyllous, scattered, more numerous along the veins, round, pulverulent, 0.2–0.5 mm. in diameter, blackish brown; teliospores ellipsoid, occasionally subclavate, 24–31 X 33–51 μ, rounded above, rounded or occasionally narrowed below, slightly constricted at the septum; wall chestnut-brown, 3–4 μ thick, moderately verrucose, pore of upper cell apical, capped by a conspicuous yellowish or hyaline umbo 3–5 μ thick, pore of lower cell midway between septum and pedicel, with a hyaline or yellowish umbo about 3 μ thick; pedicel persistent, hyaline, thin-walled, 6–8 μ wide at the point of attachment, tapering slightly downward, flexuous, up to 140 μ long; mesospores common, globoid or ovoid, 23–26 X 33–40 μ; wall chestnut-brown, 2–5 μ thick, umbo apical or subapical, irregular in shape, hyaline, yellow or cinnamon-brown, 5–10 μ thick; pedicel hyaline, thin-walled, persistent, up to 90 μ long.

HOSTS AND DISTRIBUTION: *Salvia involucrata* Cav. Guatemala.

TYPE LOCALITY: Solola, Guatemala, on *Salvia involucrata*.

ILLUSTRATIONS: Fig. 15 (from type).

SPECIMENS EXAMINED:—On *Salvia involucrata:* GUATEMALA: Solola, Jan. 30, 1915, *Holway 156* (type).

In the original description of *P. filiola* the position of the pore in the lower cell of the teliospore is said to be variable. A careful examination has revealed that in the type specimen the pore is invariably midway between the septum and the pedicel. In all other collections which have been assigned to this species the pore of the lower cell is located next to the septum. These specimens also differ from the type in having teliospores which are considerably smaller, with much shorter pedicels, and in the nature of the urediospore wall, which is usually thin and pale in the upper third but markedly thickened and darker in the basal portion. These collections are not sufficiently close to the type of *P. filiola* to constitute a variety of that species, but do agree with *P. farinacea* Long var. *constricta* Baxter, to which they have been transferred.

P. filiola is close to *P. mitrata* Syd., but has larger urediospores, mostly of Type 2, and longer, thinner-walled teliospores. The characteristic hemispherical, yellowish apical umbo and the longer pedicel are other teliospore characters which serve to distinguish *P. filiola* from *P. mitrata*.

9. PUCCINIA GENTILIS Arth., in Bull. Torrey Club **46**: 118. 1919.

Dicaeoma gentile Arth., N. Am. Flora **7**: 414. 1921.

Spermagonia and aecia unknown. Uredia amphigenous, chiefly hypophyllous, scattered, round, 0.2–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores broadly ellipsoid or obovoid, 20–23 (–27) X 23–29 (–31) μ; wall cinnamon-brown, 1.5–2 μ thick, moderately and prominently echinulate, pores 2, occasionally 3, equatorial or $\frac{1}{4}$ subequatorial. Telia amphigenous, chiefly hypophyllous, scattered, round, 0.2–0.8 mm. in diameter, pulverulent, blackish brown; teliospores broadly ellipsoid, 26–33 X 35–46 μ, rounded at both ends, not constricted at the septum; wall chestnut-brown, 4–7 μ thick, moderately to coarsely verrucose; pore of upper cell apical, of lower at the septum, each capped by a broad, brownish or yellowish umbo 3–4 μ thick; pedicel hyaline, thin-walled, persistent, flexuous, up to 100 μ long.

HOSTS AND DISTRIBUTION: *Salvia alamosana* Rose, Mexico; *Salvia guarinae* Epling, Honduras; *Salvia* sp., Mexico.

TYPE LOCALITY: Oaxaca, Mexico on *Salvia* sp.

ILLUSTRATIONS: Fig. 16 (from type).

SPECIMENS EXAMINED:—On *Salvia alamosana:* MEXICO: Oaxaca, Oct. 21, 1899, *Holway 3699*. On *Salvia guarinae:* HONDURAS: Cerro de Uyuca, Dept. Morazán, Feb. 22, 1947, *Standley & Molina 4213*. On *Salvia* sp.: MEXICO: Oaxaca, Oct. 18, 1899, *Holway 3666* (type).

This species, which resembles *P. mitrata* Syd. somewhat, was described as new by Arthur (*l.c.*) chiefly on the basis of the urediospores, which are of Type 2 and are larger and more prominently echinulate. There are in addition other differentiating characteristics not emphasized by Arthur. The teliospore wall in *P. gentilis* is uniform in thickness and brownish throughout, while in *P. mitrata* the outer layer of the wall is usually more or less irregular in thickness and is frequently yellowish or partly hyaline. This difference in color is also apparent in the umbonate portions, which are yellow or cinnamon in *P. gentilis* but are hyaline in *P. mitrata*.

P. gentilis is apparently also related to *P. porphyretica* Jacks. & Holw., a South American species. *P. porphyretica*, however, has broader teliospores with more prominent tubercles and urediospores with much thicker walls.

10. PUCCINIA MITRATA Syd., in Monogr. Ured. **1**: 294. 1902.

Dicaeoma mitratum Arth., N. Am. Flora **7**: 413. 1921.

Spermagonia epiphyllous, in groups, subepidermal, globoid, cinnamon-brown, 80–130 μ in diameter. Aecia hypophyllous, aecidioid, in groups up to 1.5 mm. across; peridial cells oblong, angularly ellipsoid or rhomboidal, 13–23 X 20–37 μ in surface view, pale yellow, outer wall 4–5 μ thick, obscurely striate, inner wall 2–3 μ thick, rather coarsely striate-verrucose; aeciospores angularly globoid, oblong, or ellipsoid, 10–20 X 16–27 μ; wall hyaline or pale yellow, 1.5–3 μ thick, closely and finely verrucose. Uredia hypophyllous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores globoid or obovoid, (13–) 16–21 X (18–) 20–23 μ; wall cinnamon-brown, 1–1.5 μ thick, moderately echinulate, pores 2, $\frac{1}{4}$–$\frac{1}{2}$ subequatorial or occasion-

ally equatorial. Telia hypophyllous, rarely caulicolous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, blackish brown; teliospores broadly ellipsoid, 26–32 X (30–) 32–43 μ, rounded at both ends, slightly or not constricted at the septum; wall chestnut-brown, 4–6 μ thick, the outer layer frequently yellowish or hyaline, coarsely verrucose, the tubercles uniting to give a striate or ridged appearance, pore of upper cell apical, of lower next to the septum, each with a hyaline or yellowish umbo, apical umbo broad, 4–6 μ thick, coarsely verrucose, with the tubercles uniting to form conspicuous striations, lateral umbo moderately to coarsely verrucose, 3–4 μ thick; pedicel hyaline, thin-walled, persistent, tapering downward, slightly flexuous or bent, up to 85 μ long.

HOSTS AND DISTRIBUTION: *Salvia kellermanii* D. Sm., Guatemala; *S. mexicana* L., Mexico; *S. polystachya* Ort., Mexico; *S. purpurea* Cav., Mexico, Guatemala; *S. sessifolia* Baker, Mexico; *S. tiliaefolia* Vahl, Mexico; *S. vitifolia* Benth., Mexico; *Salvia* sp., Guatemala.

TYPE LOCALITY: Patzcurao, Michoacan, on *Salvia mexicana*.

ILLUSTRATIONS: Sydow, Monogr. Ured. I: Tab. XIX, Fig. 279; this paper, Fig. 17 (from type).

EXSICCATI: Barth. N. Am. Ured. 247.

SPECIMENS EXAMINED:—On *Salvia kellermanii:* GUATEMALA: Finca Pirineos, Dept. Quezaltenango, Feb. 9, 1941, *Standley 87091*. On *S. mexicana:* MEXICO: Patzcuaro, Michoacan, Oct. 31, 1895, *Seler* (type); City of Mexico, Oct. 2, 1896, *Holway;* between City of Mexico and Cuernavaca, March 25, 1948, *Niederhauser*. On *Salvia polystachya:* MEXICO: Mt. Lena, Hidalgo, Oct. 10, 1946, *Moore 1448;* Patzcuaro, Michoacan, Oct. 16, 1898, *Holway 3009*. On *S. purpurea:* MEXICO: Etzatlan, Jalisco, Oct. 2, 1903, *Holway 5089;* Chapala, Sept. 25, 1899, *Holway 3500;* GUATEMALA: Calahuaché, Dept. Quezaltenango, March 1, 1939, *Standley 67115;* Cobán, Dept. Alta Verapaz, March 26–April 15, 1939, *Standley 69550;* Alameda, June 15, 1937, *Johnston 870;* Finca La Alameda, Dept. Chimaltenango, Dec. 11–22, 1940, *Standley 79758;* Mancha, July 22, 1936, *Johnston 72;* Tactic, Dept. Alta Verapaz, April 1–7, 1941, *Standley 91468;* Río Carchá, Dept. Alta Verapaz, March 26, 27, 1941, *Standley 89998, 90053;* Río Guacalate, Dept. Chimaltenango, Dec. 14–23, 1940, *Standley 81059*. On *S. sessifolia:* MEXICO: Guadalajara, Jalisco, Oct. 13, 1896, *Holway*. On *S. tiliaefolia:* MEXICO: Cuernavaca, Morelos, Sept. 27, 1898, *Holway 3028;* Patzcuaro, Michoacan, Oct. 10, 1899, *Holway 3603*. On *S. vitifolia:* MEXICO: Oaxaca, Oct. 21, 1899, *Holway 3709*. On *Salvia* sp.: GUATEMALA: Dept. Quezaltenango: Colomba, Feb. 3, 1917, *Holway 825;* Santa María, Jan. 15, 1917, *Holway 724*.

Puccinia mitrata is one of the commonest species on *Salvia* in Guatemala and southern Mexico. Some collections resemble *P. farinacea* Long, but can be distinguished by the smaller urediospores, the larger, thicker-walled teliospores, and the characteristic sculpturing of the teliospore wall. This sculpturing is particularly conspicuous on

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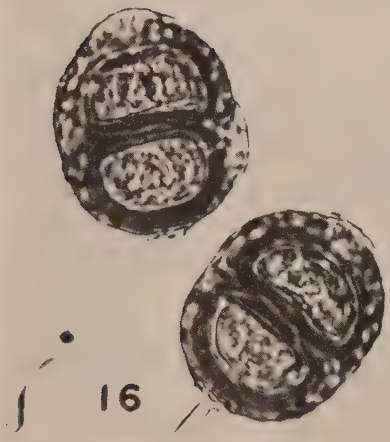
EXPLANATION OF FIGURES 14–19

FIG. 14. Teliospores of *Puccinia alamedensis*. The wall is uniform and has no marked apical thickening. (From type.) x 800. FIG. 15. Teliospores of *P. filiola*. The pore of the lower cell is located midway between the septum and the pedicel. (From type.) x 800. FIG. 16. Teliospores of *P. gentilis*. (From type.) x 800. FIG. 17. Teliospores of *P. mitrata*, showing the broad, ridged apical umbo and the pale outer layer extending down one side of the spore. (From type.) x 800. FIG. 18. Teliospores of *P. biporula*. (From type.) x 800. FIG. 19. Teliospores of *P. farinacea*. (From type.) x 800.


14


15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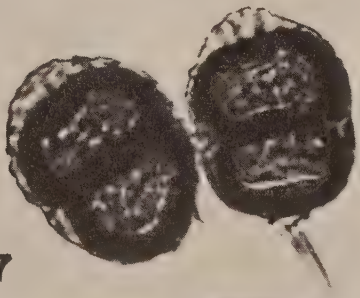
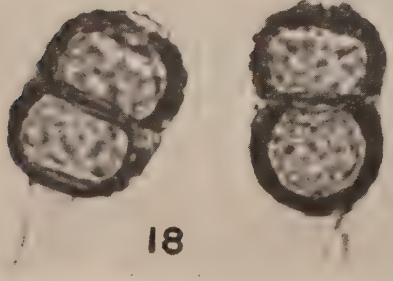

17


18


19

the apical umbo, where the tubercles unite to form evenly spaced ridges. The urediospores of *P. mitrata* are intermediate between Type 2 and Type 4.

This species is apparently closely related to a South American *Salvia* rust, *P. aenigmatica* Jacks. & Holw., from which it differs in having paler teliospores with narrower, thinner-walled pedicels.

Many specimens of *P. mitrata* are unlike the type in having the pore of the lower cell displaced downward to a position near the pedicel. This variation was first pointed out by Arthur (3). In the course of the present study, examination of the specimens of *P. mitrata* in the Arthur Herbarium has disclosed the fact that this character is constant in any given specimen; it seems advisable, therefore, to establish a variety to accomodate these variant forms.

PUCCINIA MITRATA Syd. var. **basiporula** Baxter var. nov.

A forma typica speciei differt poro cellulae inferiore in parte media sito.

HOSTS AND DISTRIBUTION: *Salvia compacta* Kuntze, Guatemala; *S. polystachya* Ort., Mexico, Guatemala, Honduras, Costa Rica; *S. purpurea* Cav., Mexico, Guatemala.

TYPE LOCALITY: Oaxaca, Mexico, on *Salvia purpurea.*

EXSICCATI: Barth. N. Am. Ured. 1561.

SPECIMENS EXAMINED:—On *Salvia compacta:* GUATEMALA: Dept. Quezaltenango: Azufral, Feb. 3, 1941, *Standley 85750;* Río Samalá, Jan. 18, 1941, *Standley 83942;* Boxantín, Jan. 16, 1941, *Standley 83808;* Zunil, Jan. 13, 1941, *Standley 83239.* On S. *polystachya:* MEXICO: Uruapan, Michoacan, Oct. 12, 1899, *Holway 3620;* Acenameca, D. F., Oct. 31, 1899, *Holway 3766;* GUATEMALA: Solola, Jan. 25, 1915, *Holway 120;* Quezaltenango, Jan. 20, 1915, *Holway 95;* HONDURAS: Cerro de Ayuca, Feb. 22, 1947, *Standley & Molina 4263;* Guinope, Jan. 5, 1947, *Standley, Williams, Molina & Padilla;* COSTA RICA: San José, Jan. 3, 1916, *Holway 348.* On *S. purpurea:* MEXICO: Oaxaca, Oct. 18, 1899, *Holway 3674* (type); San Cristobal, Chiapas, Dec. 4, 1895, *Nelson 3478;* GUATEMALA: Solola, Feb. 3, 1915, *Holway 186;* Quezaltenango, Mar. 1, 1939, *Standley 67253;* Guatemala, 1941, *Johnston.*

In this variety the germ pore in the lower cell of the teliospore is located midway between the septum and the pedicel or occasionally is next to the pedicel.

11. **Puccinia biporula** Baxter sp. nov.

Uredo biporula Arth., in Bull. Torrey Club **46**: 121. 1919.

Spermagoniis et aeciis adhuc ignotis. Urediis hypophyllis, rotundatis, 0.2–0.5 mm. diam., pulverulentis, cinnamomeo-brunneis vel castaneo-brunneis; urediosporae triangulariter obovoideae, (20–) 23–28 X (23–) 27–31 μ, vel late obovoideae, 23–29 μ latae, 20–25 μ altae; membrana basim versus obscure cinnamomea vel castaneo-brunnea, 2.5–3 (vel 4) μ cr. et sparse echinulata, apicem versus cinnamomea vel pallidiore, 1–2 μ cr. et moderate vel dense echinulata, poris germ. 2, juxta hilum sitis. Teliis hypophyllis, sparsis, rotundatis, 0.1–0.3 mm. diam., pulverulentis, atro-brunneis; teliosporae ellipsoideae vel oblongo-ellipsoideae, (20–) 23–27 X (31–) 33–43 μ, utrinque rotundatae, medio leniter vel moderate constrictae; membrana pallide castaneo-brunnea, 2–3 μ cr., moderate rugoso-verrucosa, supra poros usque ad 7 μ umbone

pallidiore incrassata, poro superiore apicali, inferiore juxta septum sito; pedicello hyalino, semipersistenti, usque ad 75 μ longo.

On leaves of *Salvia fulgens* and *Salvia gesneraeflora* in Mexico.

Spermagonia and aecia unknown. Uredia hypophyllous, scattered, round, 0.2–0.5 mm. in diameter, pulverulent, dark cinnamon- or chestnut-brown; urediospores triangular-obovoid, (20–) 23–28 X (23–) 27–31 μ, or flattened-obovoid, 23–29 X 20–25 μ; wall 1–2 μ thick above, thickened to 2.5–3 μ in the lower third, occasionally as much as 4 μ thick at the hilum, cinnamon-brown and moderately to closely echinulate above, becoming dark cinnamon- or chestnut-brown and sparsely echinulate in the lower third, spines prominent, pores 2, next to the hilum. Telia hypophyllous, scattered, roundish, 0.1–0.3 mm. in diameter, pulverulent, chocolate-brown; teliospores ellipsoid or oblong-ellipsoid, (20–) 23–27 X (31–) 33–43 μ, rounded at both ends, slightly or moderately constricted at the septum; wall light chestnut-brown, 2–3 μ thick, moderately or rather obscurely rugose-verrucose, the tubercles uniting in lines to form a reticulate pattern, pore of upper cell apical, capped by a hyaline umbo 3–4 μ thick, pore of lower cell near the septum, covered by an inconspicuous hyaline umbo 2–3 μ in thickness; pedicel hyaline, thin-walled, semi-persistent, usually collapsed, frequently broken away near the spore, slightly flexuous, up to 75 μ long.

HOSTS AND DISTRIBUTION: *Salvia fulgens* Cav., Mexico; *Salvia gesneraeflora* Lindl. & Paxt., Mexico.

TYPE LOCALITY: Real Alto, Sierra Madre Occidentale, Mexico, on *Salvia fulgens*.

ILLUSTRATIONS: Fig. 18 (from type).

SPECIMENS EXAMINED:—On *Salvia fulgens:* MEXICO: Real Alto, Sierra Madre Occidentale, Jan. 31, 1927, *Mexia 1609* (type); Amecameca, Dist. Chalco, Oct. 31, 1899, *Holway 3758* (type of *Uredo biporula*). On *S. gesneraeflora:* MEXICO: Zempoala, Morelos, Nov., 1932, *Lyonett 954;* Capulín, Dist. Valle de Bravo, April 9, 1938, *Hinton 11809*.

The distinguishing feature in *Puccinia biporula* is the basal position of the germ pores in the urediospore. The urediospore wall is also distinctive in being markedly thickened and darker in color in the lower third, the color in this portion ranging from dark cinnamon to reddish brown. The urediospores are symmetrical and are typically triangular-obovoid, although flattened-obovoid or oblate-spheroid spores are not uncommon.

Arthur (*l.c.*), in 1919, described *Uredo biporula* from a specimen collected by Holway at Amecameca, Mexico, on *Salvia fulgens*. During the preparation of the present monograph a collection of this rust on *Salvia fulgens*, bearing several telia as well as abundant uredia, was obtained from the U. S. National Herbarium. The teliospores resemble those of *P. farinacea* var. *constricta*, but are paler in color and have a more irregular type of wall sculpturing.

12. PUCCINIA FARINACEA Long, in Bull. Torrey Club **29:** 115. 1902.

Puccinia prospera Arth., Bull. Torrey Club **46:** 118. 1919.
Dicaeoma prosperum Arth., N. Am. Flora **7:** 414. 1921.
Dicaeoma farinaceum Arth., N. Am. Flora **7:** 411. 1921.

Spermagonia epiphyllous, in groups, subepidermal, globoid, cinnamon-brown, 80–130 μ in diameter. Aecia chiefly hypophyllous,

aecidioid, in groups up to 3 mm. across; peridial cells rhomboidal or rectangular, 13–15 X 35–45 μ in surface view, hyaline, outer wall 3–4 μ thick, smooth or faintly striate, inner wall 2–3 μ thick, verrucose. Uredia amphigenous, chiefly hypophyllous, scattered, round, 0.2–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores mostly oblate-spheroid, 20–25 μ broad by 16–21 μ high, occasionally obovoid or globoid, 17–23 X 20–25 μ; wall cinnamon-brown, 1–2 μ thick, moderately echinulate, pores 2, occasionally 3, somewhat variable in position, usually ¼ to ½ subequatorial, at times approximately equatorial. Telia amphigenous, usually hypophyllous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, blackish brown; teliospores broadly ellipsoid or oblong-ellipsoid, 20–28 X 27–37 (–40) μ, rounded above and below, not or slightly constricted at the septum; wall chestnut-brown, 2–4 μ thick, moderately to coarsely and irregularly verrucose, at times obscurely verrucose and appearing smooth in the lower half, pore of upper cell apical, of lower next to the septum, apical umbo hyaline, 3–4 μ thick, lateral umbo hyaline or yellowish, 2.5–3 μ thick; pedicel hyaline, thin-walled, persistent, frequently collapsed, slightly flexuous, up to 80 μ long.

HOSTS AND DISTRIBUTION: *Salvia amarissima* Ort., Mexico, Guatemala; *S. arbuscula* Fern., Mexico; *S. dasycalyx* Fern., Mexico; *S. farinacea* Benth., U.S.A. (Texas); *S. microphylla* H.B.K. (*S. grahami* Benth.), Mexico; *S. nepetoides* H.B.K., Guatemala; *S. patens* Cav., Guatemala; *Salvia* sp., Guatemala.

TYPE LOCALITY: Austin, Texas, U.S.A., on *Salvia farinacea*.

ILLUSTRATIONS: Long, Bull. Torrey Club **29:** Plate 15, Fig. 6; Sydow, Monogr. Ured. I: Tab. XX, Fig. 277; Arthur, Manual of Rusts, Fig. 410; this paper, Fig. 19 (from type).

EXSICCATI: Barth. Fungi Columb. 2450.

SPECIMENS EXAMINED:—On *Salvia amarissima:* MEXICO: Pachuca, Hidalgo, Sept., 1905, *Purpus 1724;* Morelia, Michoacan, Oct. 8, 1899, *Holway 3590;* Pachuca, Hidalgo, Oct. 5, 1899, *Holway 3574;* Oaxaca, Oct. 17, 1899, *Holway 3650;* GUATEMALA: Antigua, March 2, 1916, *Holway 547.* On *S. arbuscula:* MEXICO: Puerto Zarzamora, Michoacan, April 28, 1939, *Hinton 13729.* On *S. dasycalyx:* MEXICO: Coalcoman, Michoacan, Feb. 3, 1939, *Hinton 12930.* On *S. farinacea:* U.S.A.: Austin, Texas: Nov. 12, 1901, *Long 833* (type); April 4, 1901, *Long;* May 4, 1901, *Long;* Nov. 10, 1914, *Lewis & Tharp 38;* Nov., 1900, *Long 46.* On *S. microphylla:* MEXICO: Serrania de Ajusco, D. F., Nov. 9, 1903, *Pringle 11688;* Sierra de las Cruces, Oct. 23, 1892, *Pringle 4298;* Morelia, Michoacan, Nov., 1910, *Arsene 5671;* Toluca, D. F., Sept. 17, 1898, *Holway 3136;* Pachuca, Hidalgo, Oct. 5, 1899, *Holway 3579* (type of *Puccinia prospera*). On *S. nepetoides:* GUATEMALA: Quezaltenango, Jan. 20, 1915, *Holway 94.* On *S. patens:* GUATEMALA: San Martín, Chile Verde, Jan. 8, 1941, *Johnston 1761.* On *Salvia* sp.: GUATEMALA: Huehuetenango, Jan. 23, 24, 1917, *Holway 773, 777;* Cumbre del Aire, Jan. 1, 1937, *Johnston 521.*

The geographical range of *Puccinia farinacea* includes Guatemala, Mexico, and in the southern and central United States. It is the most commonly collected *Salvia* rust in Mexico and Guatemala, and is the most variable of the North American species, tending to intergrade with *P. mitrata* and *P. infrequens* Holw. It can be distinguished from *P. mitrata* by the smaller, thinner-walled teliospores and larger urediospores. The teliospores differ from those of *P. infrequens* in being more coarsely verrucose and in having persistent pedicels.

Specimens of *P. farinacea* on *Salvia azurea* from the southern and central United States resemble *P. caulicola* with respect to telial characters. The telia in these specimens are occasionally caulicolous as well as foliicolous and bear teliospores which are much like those of *P. caulicola*, but differ in having thin-walled pedicels and more conspicuously verrucose walls. Although these collections undoubtedly belong in *P. farinacea* they constitute a distinct variety, designated in this paper as *azurea*. Another variant form which occurs in Guatemala and southern Mexico is segregated as variety *constricta*.

In studying the relationship of *P. farinacea* to other species it was found that *P. prospera*, a species described in 1921 by Arthur (*l.c.*), is identical with *P. farinacea*. Arthur described *P. prospera* primarily on the basis of the size and wall sculpturing of the teliospores. The type collection, on *Salvia microphylla*, has teliospores which fall within the size range for *P. farinacea;* moreover, the sculpturing of the wall resembles that of some of the forms of the latter species. The scanty type material has been supplemented, during the present study, by specimens on *S. microphylla* obtained from the U. S. National Herbarium. Examination of teliospores from these collections has revealed that the pedicel is persistent.

A rather aberrant condition in one collection of *P. farinacea* from Guatemala is worthy of mention. This specimen, Holway's No. 3650 on *S. amarissima*, has all spore forms present. In addition to the typical overwintering spores, however, the telia contain numerous pale, thin-walled, nearly smooth teliospores. These spores are borne on short, fragile pedicels and germinate without a resting period. The occurrence of this type of teliospore in a full-cycle rust such as *P. farinacea* is somewhat anomalous, and in view of the fact that only one specimen exhibits this phenomenon, it probably should be considered an abnormal condition.

The urediospores of *P. farinacea* show considerable variability in shape and in the location of the germ pores. In most specimens Type 4 spores predominate. The germ pores are usually midway between the equator and the hilum.

PUCCINIA FARINACEA Long var. **azurea** Baxter var. nov.

A forma typica speciei differt urediosporae plerumque late ellipsoideae vel globoideae, poris germ. 2, aequatorialibus; teliis amphigenis, 0.3–1.5 mm. diam., et caulicolis, usque ad 3 mm. diam., teliosporae variabiles, subinde plus minusve oblongae et utrinque obtusae vel attenuatae, membrana obscure verrucosa, subinde manifeste levibus.

HOSTS AND DISTRIBUTION: *Salvia azurea* Michx., U. S. A. (Alabama, Florida, Texas, Mississippi); *Salvia azurea* Michx. subsp. *pitcheri* (Torr.) Epling, U. S. A. (Nebraska, Kansas, Oklahoma); *Salvia* sp., U. S. A. (Florida).

TYPE LOCALITY: Birmingham, Alabama, on *Salvia azurea*.

EXSICCATI: Barth. N. Am. Ured. 631, 3243; Ell. & Ev. Fungi Columb. 1867 (as *P. salviae-lanceolatae* Bubák); Ell. & Ev. N. Am. Fungi 1458 (as *P. nigrescens* Peck); Barth. Fungi Columb. 3654; Kell. & Sw. Kans. Fungi 43 (as *P. nigrescens* Peck).

SPECIMENS EXAMINED:—On *Salvia azurea:* U.S.A.: Birmingham, Ala., Oct. 4, 1924, *Bartholomew* (type); Jacksonville, Fla., Oct. 27, 1894, *Curtiss 5276;* Cocoa, Ala., Oct. 13–15, 1896, *Schuchert;* Shamrock, Texas, Oct. 14, 1945, *Cory;* Ocean Springs, Miss., Oct. 15, 1893, *Earle.* On *S. azurea* subsp. *pitcheri:* U.S.A.: Bourbon Co., Kans., May 28, 1902, *Garrett 45;* Lincoln, Neb., Sept. 25, 1900, *Bates 1549;* Red Cloud, Neb., May 25, 1903, *Bates 2842;* Louisville, Kans., Oct. 14, 1911, *Bartholomew;* Cache, Okla., Sept. 30, 1912, *Long 4567;* Manhattan, Kans., Aug., 1882, *Kellerman 1852,* Sept. 20, 1888, *Kellerman,* Stillwater, Okla., Sept. 16, 1893, *Waugh.* On *Salvia* sp.: U.S.A.: Winter Park, Fla., Dec. 10, 1939, *Shear.*

The urediospores of variety *azurea* are chiefly of Type 2, while in the main species Type 4 is predominant. The teliospores of this variety are rather variable and may be broadly ellipsoid, oblong, or subclavate. The telia resemble those of *P. caulicola* in being rather compact and occasionally caulicolous.

PUCCINIA FARINACEA Long var. **constricta** Baxter var. nov.

A forma typica speciei differt urediosporae plerumque triangulariter obovoideae vel late obovoideae, membrana basim versus obscure cinnamomea, 2–2.5 μ cr., apicem versus frequenter pallidiore et 1 μ cr., poris germ. 2 (vel 3), in parte sporae inferiore semidepressis; teliosporae longiore, 23–29 X (30–) 32–42 (–45) μ, ad septum lenissime vel plus minusve valde constrictae, membrana uniformiter verrucosa, pedicello usque ad 90 μ longo.

HOSTS AND DISTRIBUTION: *Salvia dorisiana* Standl., Honduras; *S. elegans* Vahl, Guatemala, Mexico; *S. holwayi* Blake, Guatemala; *S. lavanduloides* Kunth., Guatemala; *S. karwinskii* Benth. (*S. lindenii* Benth.), Guatemala; *S. nervata* M. & G., Guatemala; *S. polystachya* Ort., Mexico; *S. pulchella* DC., Guatemala, *Salvia* sp., Guatemala.

TYPE LOCALITY: Volcan de Agua, Guatemala on *Salvia karwinskii.*

SPECIMENS EXAMINED:—On *Salvia dorisiana:* HONDURAS: Cerro de Uyuca, Dept. Morazán, Nov. 25–Dec. 5, 1946, *Standley & Williams 808.* On *S. elegans:* GUATEMALA: Sija, Dept. Quezaltenango, Jan. 26, 1917, *Holway 780;* Solola, Jan. 28, 1915, *Holway 140;* MEXICO: Amecameca, D. F., October 31, 1899, *Holway 3764.* On *S. holwayi:* GUATEMALA: Río Samalá, Dept. Quezaltenango, Jan. 18, 1941, *Standley 83951;* San Francisco El Alto, Dept. Totonicapán, Jan. 19, 1941, *Standley 84131, 83973;* San Juan Ostuncalco, Dept. Quezaltenango, Jan. 30, 1941, *Standley 85262;* Zunil, Dept. Quezaltenango, Jan. 13, 1941, *Standley 83198;* Quezaltenango, Jan. 18, 1917, *Holway 741.* On *S. lavanduloides:* GUATEMALA: Antigua, Dec. 28, 1916, *Holway 654;* Finca La Alameda, Dept. Chimaltenango, Dec. 11–22, 1940, *Standley 79726;* San Francisco El Alto, Dept. Totonicapán, Jan. 19, 1941, *Standley 84138;* Solola, Guatemala, Jan. 30, 1915, *Holway 165.* On *S. karwinskii:* GUATEMALA: Volcán de Agua, Antigua, Jan. 13, 1915, *Holway 88,* March 7, 1916, *Holway 580* (type); Columba, Feb. 4, 1917, *Holway 833.* On *S. nervata:* GUATEMALA: Zunil, Dept. Quezaltenango, Feb. 3, 1941, *Standley 85806;* Chemal, Dept. Huehuetenango, Dec. 31, 1940, *Johnston 1931.* On *S. polystachya:* MEXICO: Cuernavaca, April 16, 1948, *Niederhauser & Zenteno 709.* On *S. pulchella:* GUATEMALA: San Rafael, Dept. Guatemala, Jan. 7, 1915, *Holway 19A,* Jan. 9, 1915, *Holway 41A;* Totonicapán, Jan. 24, 1915, *Holway 107.* On *Salvia* sp.: GUATEMALA: Palestina, Dept. Quezaltenango, Feb. 22, 1939, *Standley 66326;* Volcán de Agua, Antigua, March 7, 1916, *Holway 579.*

This variety differs from the main species in several respects. The teliospores are larger, with slightly longer pedicels, and as a rule the spore walls are more evenly verrucose. The chief differentiating urediospore character is the nature of the wall, which is thickened and dark cinnamon-brown at the base, while the upper portion is thin and subhyaline. The urediospores are intermediate between Types 2 and 4.

Certain collections of variety *constricta* approach *P. filiola*, but can be readily distinguished from that species by the smaller, thinner-walled teliospores with shorter pedicels.

13. PUCCINIA CUILAPENSIS Cumm., in Bull. Torrey Club **70:** 74. 1943.

Spermagonia and aecia unknown. Uredia amphigenous, mostly hypophyllous, scattered, round, 0.2–0.4 mm. in diameter, pulverulent, pale golden-yellow, urediospores broadly ellipsoid or obovoid, 17–22 X 20–27 μ, wall pale yellow or nearly hyaline, 1–1.5 μ thick, moderately echinulate, pores 2, equatorial, obscure. Telia hypophyllous, scattered, round, 0.2–0.5 mm. in diameter, pulverulent, blackish brown; teliospores broadly ellipsoid, (20–) 26–30 (–32) X (30–) 37–43 (–45) μ, rounded at both ends, slightly constricted at the septum; wall chestnut-brown, 3–4 μ thick, moderately and irregularly verrucose, pore of upper cell apical or subapical, of lower near the septum, each capped by a rather inconspicuous hyaline umbo 2–4 μ thick; pedicel hyaline, thin-walled, semi-persistent, usually collapsed, up to 80 μ long.

HOSTS AND DISTRIBUTION: *Salvia gracilis* Benth., Guatemala; *Salvia mocinoi* Benth., Guatemala; *Salvia* sp., Guatemala.

TYPE LOCALITY: Cuilapa, Dept. Santa Rosa, Guatemala, on *Salvia mocinoi*.

ILLUSTRATIONS: Cummins, Bull. Torrey Club **70:** Fig. 8; this paper, Fig. 20 (from type).

SPECIMENS EXAMINED:—On *Salvia gracilis:* GUATEMALA: Volcán de Zunil, Dept. Quezaltenango, Feb. 3, 1941, *Standley 85744, 85830*. On *S. mocinoi:* GUATEMALA: Cuilapa, Dept. Santa Rosa, Nov. 20–27, 1940, *Standley 78545* (type); Laguna, Dept. Amatitlan, Jan. 25, 1906, *Kellerman 5472;* EL SALVADOR: Ataco, Dept. Ahuachapán, Jan. 19, 1947, *Standley & Padilla 2645*. On *Salvia* sp.: GUATEMALA: Cuilapilla, Dept. Santa Rosa, Nov. 23, 1940, *Standley 78008;* Laguna, Dept. Amatitlan, Jan. 25, 1906, *Kellerman 5471*.

Puccinia cuilapensis, which is apparently closely related to *P. farinacea*, is distinct in having pale yellow or hyaline urediospores which give the uredia a characteristic golden color. The urediospores are of Type 2. The teliospores resemble those of *P. farinacea* var. *constricta* but differ in having more uniform walls with rugose sculpturing. The pore of the upper cell frequently occupies a subapical position, and is capped by a rather inconspicuous umbo.

14. PUCCINIA INFREQUENS Holw., in Jour. Mycol. **11:** 158. 1905.
Dicaeoma infrequens Arth., N. Am. Flora **7:** 413. 1921.

Spermagonia epiphyllous, in groups, subepidermal, flattened-globoid, cinnamon-brown, 65–130 μ in diameter. Aecia amphigenous and caulicolous, chiefly hypophyllous, aecidioid, in groups up to 1.5 mm. across on leaves, to 4 mm. long on stems; peridial cells oblong or rhomboidal, 14–26 X 25–43 μ in surface view, wall pale cinnamon-brown, 3–5 μ thick, finely verrucose. Uredia hypophyllous, scattered, round, 0.2–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores asymmetrically oblate-spheroid, 16–23 X 16–23 μ with pores in surface view, 18–25 μ broad by 16–23 μ high with pores in optical section, or globoid or obovoid, 16–23 X 20–25 μ; wall pale cinnamon-brown, 1–1.5 μ thick, moderately echinulate, pores 2, occasionally 3, equatorial or ¼ sub-

equatorial. Telia hypophyllous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, chestnut-brown; teliospores broadly ellipsoid or oblong-ellipsoid, 20–27 X 26–35 (–40) μ, rounded at both ends, slightly or not constricted at the septum; wall cinnamon- or light chestnut-brown, 1.5–3 μ thick, closely and finely verrucose, pore of upper cell apical, of lower next to the septum, each with a hyaline, finely verrucose umbo about 3 μ thick; pedicel hyaline, thin-walled, fragile, breaking at or near the point of attachment.

HOSTS AND DISTRIBUTION: *Salvia cinnabarina* M. & G., Honduras, Guatemala, Mexico; *Salvia urica* Epling, Guatemala.

TYPE LOCALITY: Oaxaca, Mexico, on *Salvia cinnabarina*.

ILLUSTRATIONS: Fig. 21 (from type).

EXSICCATI: Barth N. Am. Ured. 1453.

SPECIMENS EXAMINED:—On *Salvia cinnabarina:* HONDURAS: Dept. Comayagua: El Achote, Feb. 18, 1928, *Standley 56111O;* Dept. Morazán: La Montanita, Dec. 2, 1946, *Standley 516;* Cerro de Ayuca, Feb. 22, 1947, *Standley & Molina 4220;* GUATEMALA: Dept. Huehuetenango: Aguacatán, Dec. 27, 1940, *Standley 81321;* Huehuetenango, Jan. 23, 1917, *Holway 768;* Dept. Totonicapán: San Francisco El Alto, Jan. 19, 1941, *Standley 84078;* Dept. Quezaltenango; Volcán de Santa María, Jan. 15, 1941, *Standley 83574;* Palestina, Jan. 21, 1941, *Standley 84367;* Quezaltenango, Jan. 21, 1915; Jan. 16, 18, 1917, *Holway 99, 727, 751;* Antigua: Volcán de Agua, Jan. 13, 1915, Mar. 2, 4, 1916, *Holway 78, 546, 552;* Dept. Guatemala; San Rafael, Jan. 7, 1915, *Holway 19B;* Dept. Solola: Atitlan, Feb. 16, 1906, *Kellerman 5438;* Dept. Amatitlan: Moran, Feb. 11, 1905, *Kellerman 4623;* MEXICO: Oaxaca, Oct. 18, 1899, *Holway 3669* (type). On *S. urica:* GUATEMALA: Mancha, Aug. 5, 1936, *Johnston 77;* Dept. Sacatepéquez: Antigua, Jan. 27, 1939, *Standley 63710;* Chimaltenango: Finca La Alameda, Dec. 11–12, 1940, *Standley 79779;* Dept. Quezaltenango: Volcán de Santa Maria, Jan. 15, 1941, *Standley 83575;* Río Samalá, Jan. 18, 1941, *Standley 83949;* Palestina, Jan. 30, 1941, *Standley 85247;* Dept. Huehuetenango: Puente de Xinaxo, Dec. 30, 1940, *Standley 81588.*

The light brown, finely verrucose teliospores with fragile pedicels typify this species, which is close to *P. farinacea.* The urediospores are thin-walled and rather pale, and may be symmetrical or asymmetrical, with spores of Types 3 and 4 occurring in the same sorus.

Collections of *P. infrequens* on *Salvia urica* differ somewhat from the type, the teliospores being darker in color, with semi-persistent pedicels, and showing some resemblance to those of *P. farinacea.*

15. PUCCINIA BALLOTAEFLORAE Long, in Bull. Torrey Club **29**: 116. 1902.

Dicaeoma ballotaeflorae Arth., N. Am. Flora **7**: 412. 1921.

Spermagonia and aecia unknown. Uredia hypophyllous, scattered, round, 0.1–0.7 mm. in diameter, pulverulent, cinnamon-brown; urediospores broadly obovoid, triangular-obovoid or broadly ellipsoid, 19–23 X 23–27 μ; wall cinnamon-brown, 1.5–2 μ thick, moderately and finely echinulate, pores 3 or 4, 2 or 3 equatorial or ¼ subequatorial, 1 apical or subapical. Telia amphigenous, scattered, round, 0.1–0.4 mm. in diameter, compact, becoming pulverulent, blackish brown; teliospores ellipsoid or oblong-ellipsoid, (20–) 23–27 X (30–) 32–43 μ, rounded at both ends, not or slightly constricted at the septum; wall dark chestnut- or chocolate-brown, 2–4 μ thick, coarsely and irregularly verrucose, pore of upper cell apical, of lower next to the septum, each with a low

brownish umbo 2–3 μ thick; pedicel hyaline, thin-walled, persistent, frequently attached obliquely, up to 90 μ long.

HOSTS AND DISTRIBUTION: *Salvia ballotaeflora* Benth., U.S.A.; Mexico.

TYPE LOCALITY: San Marcos, Texas, U.S.A., on *Salvia ballotaeflora*.

ILLUSTRATIONS: Long, Bull. Torrey Club **29:** Plate 15, Fig. 7; this paper, Fig. 22 (from type).

EXSICCATI: Barth. N. Am. Ured. 2141.

SPECIMENS EXAMINED:—On *Salvia ballotaeflora:* U.S.A.: Texas: San Marcos, Nov. 19, 1900, *Long 836* (type); Austin, Nov., 1900, *Long;* Nov. 7, 1916, *Long 6146;* Del Rio, Nov. 6, 1916, *Long 6080;* MEXICO: El Carriso, N. L., Nov. 6, 1903, *Lorano.*

The presence of an apical pore in the urediospore distinguishes *Puccinia ballotaeflorae* from other North American *Salvia* rusts. This species, together with *P. diutina* Mains & Holw. and *P. badia* Holw., represents a group of closely related forms characterized by having dark brown, coarsely verrucose teliospores, the pedicels of which are frequently displaced laterally.

The urediospores are described by Arthur (*l.c.*) as having three or four pores, two being subequatorial and one or two apical. Actually there may be two or three pores in the equatorial zone, while there is only one at the apex. In shape and symmetry the urediospores are of Type 2.

Up to the present time *P. ballotaeflorae* has been known only from the United States. The range is here extended to include northeastern Mexico, on the basis of Lorano's specimen from Nuevo Leon.

16. PUCCINIA DIUTINA Mains & Holw., Arth., in Mycologia **10:** 136. 1918.

Dicaeoma diutinum Arth., N. Am. Flora **7:** 413. 1921.

Spermagonia epiphyllous, in groups, subepidermal, globoid, cinnamon-brown, 95–180 μ in diameter. Aecia hypophyllous, aecidioid, roundish, solitary or clustered in groups up to 2 mm. in diameter; peridial cells irregular in shape, chiefly rhomboidal or rectangular, 13–33 X 27–47 μ in surface view, hyaline, outer wall thick, 5–13 μ, obscurely striate; inner wall thin, 1.5–3 μ, closely and finely verrucose; aeciospores variable, mostly angularly globoid or broadly ellipsoid, 16–30 X 23–40 μ; wall hyaline, unevenly 2–7 μ thick, finely and closely verrucose. Uredia amphigenous, scattered, round, 0.1–0.5 mm. in diameter, pulverulent, cinnamon-brown; urediospores globoid or oblate-spheroid, rounded apically and flattened at the base, (19–) 23–26 (–27) μ broad by 16–23 (–25) μ high; wall 2 μ thick and dark cinnamon brown above, becoming abruptly 1 μ or less in thickness and colorless in the lower third, moderately echinulate, pores 2, rarely 3, obscure, near the hilum. Telia amphigenous, scattered, roundish, 0.1–0.4 mm. in diameter, pulverulent, blackish brown; teliospores oblong or broadly ellipsoid, 23–26 X 26–33 (–39) μ, rounded apically, rounded or obtuse below, slightly or not constricted at the septum; wall dark chestnut-brown, 2–3 μ thick, thickened apically to 4–5 μ, coarsely verrucose; pore of upper cell apical, of lower next to the septum, each with a dark brown umbo 2–3 μ thick; pedicel hyaline, thin-walled, usually persistent, occasionally attached obliquely, variously bent, up to 60 μ in length.

HOSTS AND DISTRIBUTION: *Salvia chrysantha* M. & G., Mexico; *Salvia pittieri* Briq., Costa Rica; *Salvia scorodoniaefolia* Poir., Mexico.

TYPE LOCALITY: Near Cartago, Costa Rica, on *Salvia pittieri*.

ILLUSTRATIONS: Fig. 23 (from type).

SPECIMENS EXAMINED: On *Salvia chrysantha:* MEXICO: Oaxaca, Oct. 21, 1899, *Holway 3698*. On *S. pittieri:* COSTA RICA: Near Cartago, Dec. 23, 1915, *Holway 290* (type). On *S. scorodoniaefolia:* MEXICO: Chapala, Jalisco, Sept. 24, 1899, *Holway 3493*.

The teliospores of *Puccinia diutina* resemble those of *P. badia* somewhat. In *P. diutina*, however, the pore of the upper cell is apical, while in *P. badia* both pores are next to the septum beneath a common umbo-like thickening. The urediospores of *P. diutina* are unlike those of any other rust in this group, the wall being dark cinnamon and markedly thickened in the upper two-thirds, while the basal portion is hyaline and thin. The urediospores are of Type 6.

17. PUCCINIA BADIA Holw., in Jour. Mycol. **11**: 158. 1905.
Diaceoma badium Arth., N. Am. Flora **7**: 412. 1921.

Spermagonia and aecia unknown. Uredia hypophyllous, scattered, round, 0.1–0.3 mm. in diameter, pulverulent, cinnamon-brown; urediospores broadly obovoid with pores in surface view, triangular-obovoid with pores in optical section, 16–23 X 16–24 μ; wall pale cinnamon-brown, 1 μ thick, finely and closely echinulate, pores 2, obscure, $\frac{1}{4}$ subequatorial. Telia hypophyllous, scattered, round, 0.1–0.3 mm. in diameter, pulverulent, blackish-brown, teliospores variable, usually oblong or broadly ellipsoid, at times angularly globoid or nearly cubical, 19–24 (–27) X 23–33 μ, rounded or obtuse at both ends, not constricted at the septum; wall chocolate-brown, 2–3.5 (–4.5) μ thick, coarsely verrucose, both pores near the septum, with a common chestnut-brown umbo 2–3 μ thick; pedicel hyaline, faintly colored next to the spore, thin-walled, persistent, frequently attached obliquely, rarely at the septum, up to 60 μ long.

HOSTS AND DISTRIBUTION: *Salvia albicans* Fern., Mexico.

TYPE LOCALITY: Iguala, Guerrero, Mexico, on *Salvia albicans*.

ILLUSTRATIONS: Fig. 24 (from type).

SPECIMENS EXAMINED:—On *Salvia albicans:* MEXICO: Iguala, Guerrero, Nov. 4, 1903, *Holway 5332* (type); Oct. 3, 1900, *Holway;* Sept. 3, 1900, *Holway*.

The teliospores show considerable variability in the attachment of the pedicel, which may be inserted at right angles to the septum,

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EXPLANATION OF FIGURES 20–26

FIG. 20. Teliospores of *Puccinia cuilapensis*. (From type.) x 800. Fig. 21. Teliospores of *P. infrequens*. (From type.) x 800. FIG. 22. Teliospores of *P. ballotaeflorae*. (From type.) x 800. FIG. 23. Teliospores of *P. diutina*. (From type.) x 800. FIG. 24. Teliospores of *P. badia*. The pedicel is frequently attached obliquely. Note the thickening of the wall at the septum on the side distal to the pedicel. (From type.) x 800. FIG. 25. Teliospores of *P. vertisepta*. The pedicel is thick-walled and is attached at the septum. (From Parry & Palmer 741.) x 800. FIG. 26. Teliospores of *P. vertiseptoides*. The pores, as in *P. vertisepta*, are next to the vertical septum beneath a common umbo. The two spores at the right are of the thin-walled type in which germination occurs without a rest period. (From type.) x 800.


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in an oblique position, or rarely in line with the septum. In this respect *Puccinia badia* appears to be intermediate between *P. diutina* and *P. vertisepta*. It resembles the latter species in having both germ pores in the teliospore located next to the septum. This is apparently the typical position regardless of the point of attachment of the pedicel, although the opacity of the spore wall often makes observation of the pores difficult. The urediospores in *P. badia* are of Type 5.

18. PUCCINIA VERTISEPTA Tracy & Gall., in Jour. Mycol. **4**: 21. Mar. 1888.

Diorchidium tracyi De T., in Sacc. Syll. Fung. **7**: 736. Oct. 1888.
Allodus vertisepta Arth., Résult. Sci. Congr. Bot. Vienne 345. 1906.

Spermagonia epiphyllous, in groups, subepidermal, globoid, cinnamon-brown, 80–130 μ in diameter. Aecia hypophyllous, aecidioid, in groups up to 1 mm. in diameter; peridial cells angularly ovoid or oblong, 16–23 X 23–37 μ in surface view, pale cinnamon-brown or nearly hyaline, outer wall 2–5 μ thick, obscurely striate, appearing smooth, inner wall 1.5–2 μ thick, finely verrucose; aeciospores angularly ovoid or subgloboid, 15–33 X 23–33 μ; wall pale cinnamon-brown, 1.5–2 μ thick at the sides, thickened to 3–4 μ at the base and apex, finely and closely verrucose; urediospores in the telia, asymmetrical, ellipsoid or obovoid with pores in surface view, ellipsoid-oblong and narrower with pores in optical section, 15–21 (–23) X 23–27 μ; wall cinnamon-brown, 1.5 μ in thickness, thickened to 2.5 (–3) μ at the hilum, moderately echinulate, pores 2, equatorial. Telia amphigenous, occasionally also caulicolous, scattered, roundish, 0.2–1 mm. in diameter, pulverulent, blackish brown; teliospores diorchidioid, cubical in face view, globoid or broadly ellipsoid in lateral view, 26–33 (–35) X (28–) 30–35 (–37) μ; wall dark chestnut- or chocolate-brown, 3–4 μ thick, coarsely verrucose, pores apical beneath a common umbo and next to the vertical septum, umbo light chestnut-brown, 4–6 μ thick, coarsely verrucose; pedicel hyaline with a brownish tint next to the spore, thick-walled, persistent, attached at the septum, tapering downward, flexuous, up to 130 μ long.

HOSTS AND DISTRIBUTION: *Salvia pinguifolia* (Fern.) W. & S., U.S.A., *Salvia regla* Cav., Mexico.

TYPE LOCALITY: New Mexico, U.S.A., on *Salvia pinguifolia*.

ILLUSTRATIONS: Galloway, Jour. Mycol. **5**: Plate 10, Figs. 3 & 4; Arthur *et al*, Plant Rusts, Fig. 145; this paper, Fig. 25.

EXSICCATI: Solheim, Mycofl. Saximont. Exsic. 277.

SPECIMENS EXAMINED:—On *Salvia pinguifolia:* U.S.A., Clifton, Ariz.: Nov., 1934, *Capron;* Oct. 6, 1939, *Goodding & Mallery*. On *S. regla:* MEXICO: Region of San Luis Potosi, 1878, *Parry & Palmer 741*.

The strictly diorchidioid teliospores distinguish *Puccinia vertisepta* and the closely related species *P. vertiseptoides* Cumm. from other *Salvia* rusts. *P. vertisepta* is also distinct in being the only North American species having Type 1 urediospores.

The illustration of teliospores of this species by Arthur (*l.c.*) shows two teliospores, one of which is the normal diorchidioid type, while the

other has the septum at right angles to the pedicel. The latter condition actually is extremely rare and must be regarded as an abnormality.

Prior to the collection of the Arizona specimens on *S. pinguifolia* certain erroneous ideas prevailed regarding *P. vertisepta* which account for the discrepancies between the original description published by Tracy and Galloway (*l.c.*) and subsequent descriptions. As has been pointed out by Cummins (7), these misconceptions can be traced to Holway's data based on Mexican collections on *Salvia sessei* and on an examination of a fragment of the type collection in the Missouri Botanical Garden. Although urediospores had been described for this species by Tracy and Galloway and had been illustrated by Galloway (*l.c.*), Holway concluded that the type specimen, as well as his collections on *S. sessei*, bore aecia and telia but lacked uredia or urediospores. Holway's findings were accepted by Orton (12) and Arthur (2). The later collections from Arizona, however, were found to bear abundant urediospores which agreed with the original description and illustration. Cummins found Holway's Mexican rust to differ from the Arizona collections of *P. vertisepta* not only in lacking uredia and urediospores but in several other respects as well. The rust on *S. sessei* was accordingly segregated as *P. vertiseptoides*.

19. PUCCINIA VERTISEPTOIDES Cumm., in Ann. Mycol. **38**: 338. 1940.

Spermagonia amphigenous, chiefly epiphyllous, in groups, subepidermal, flattened-globoid, cinnamon-brown, 80–150 μ in diameter. Aecia amphigenous, chiefly epiphyllous, aecidioid, clustered around the spermagonia on yellow circular spots 1–6 mm. across; peridial cells rhomboidal, oblong or ellipsoid, 16–24 X 28–46 μ in surface view, hyaline, outer wall 3–5 μ thick, nearly smooth, inner wall 2–3 μ, finely verrucose; aeciospores variable, ovoid, ellipsoid, angularly pyriform or subclavate, 14–23 X 23–36 (–46) μ, wall golden-yellow, 2–4 μ thick, thickened apically and basally to 5–13 μ, coarsely verrucose. Uredia unknown, probably lacking. Telia amphigenous, scattered, round, pulverulent, 0.1–0.3 (–0.5) mm. in diameter, blackish brown; teliospores diorchidioid, of two types, lepto-form and resting spores, lepto-form spores thin-walled, germinating without a resting period, cubical or cubically globoid in face view, globoid in lateral view, 21–27 X 24–30 μ; wall light chestnut-brown, 2–3 μ thick, minutely verrucose or finely striate, appearing smooth; both pores apical next to the vertical septum, capped by a common light chestnut- or cinnamon-brown umbo 4–6 μ thick; pedicel hyaline, thin-walled, fragile, usually broken off at or near the spore, attached at the septum, occasionally 30–40 μ long; resting spores thick-walled, germinating only after a resting period, cubical or cubically globoid in face view, globoid in lateral view, 24–30 X 24–33 μ; wall dark chestnut- or chocolate-brown, 3–4 μ thick, moderately to coarsely verrucose, both pores apical next to the vertical septum, with a common chestnut-brown umbo 4–6 μ thick; pedicel hyaline with a faint brownish tint near the point of attachment, thin-walled, semi-persistent, frequently collapsed or broken away near the spore, attached at the septum, up to 70 μ long.

HOSTS AND DISTRIBUTION: *Salvia regla* Cav., Mexico; *S. sessei* Benth., Mexico.

TYPE LOCALITY: Cuernavaca, Mexico, on *Salvia sessei*.

ILLUSTRATIONS: Fig. 26 (from type).

EXSICCATI: Barth. N. Am. Ured. 275, 875 (both as *P. vertisepta* Tracy & Gall).

SPECIMENS EXAMINED:—On *Salvia regla:* MEXICO: Papasquiaro, Durango, Aug. 7, 1898, *Nelson 4663*. On *S. sessei:* MEXICO: Jungapeo, Michoacan, Dec., 1937, *Martinez 148;* Cuernavaca, Morelos, Sept. 30, 1899, *Holway 3539* (type), Sept. 26, 1898, *Holway 3012*, Oct. 18, 1900, *Pringle 8375, 8378*.

Puccinia vertiseptoides is closely related to *P. vertisepta* and probably is a correlated species. The chief distinguishing characteristics are the absence of urediospores, the pronounced apical and basal thickening in the aeciospore wall, and the presence in the telia of light brown, smooth-walled teliospores which germinate without a resting period. These spores are accompanied by dark brown, rough-walled overwintering teliospores much like those of *P. vertisepta*. The existence of these two types of spores in this species has not been previously emphasized. A similar condition has been observed by Dietel (8) and Jorstad (10) in certain lepto-species of *Puccinia*.

Holway (9), in his notes on this species, erroneously described the germ pores in the teliospore as being variable in position. Examination of germinated spores shows that the pores are invariably located apically next to the septum.

EXCLUDED SPECIES

Puccinia nivea Holw., Jour. Mycol. **11**: 158. 1905. This species has sessile teliospores and is the type of the genus *Polioma*, which has recently been reinstated by Baxter & Cummins (5) to accomodate four species having two-celled sessile teliospores.

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Taxonomic Notes on the Rosaceae of Formosa

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A critical review of the family Rosaceae as it occurs on the island of Formosa (Taiwan) has been made with particular emphasis on the relationships of the various species with those of the same genera in the neighboring floras. Such a coordinated study was much neglected in former work on the Formosan flora. This research was carried on mainly at the U. S. National Herbarium, where large series of specimens from mainland China, Hainan, the Philippine and Liukiu Islands, and Japan are available for reference. A grant from the U. S. Department of State aided this study, and the writer is also indebted to the American Philosophical Society for an earlier grant which enabled him to study Formosan plants in the field and in some Chinese herbaria.

While a complete presentation of the family is reserved for a future floristic work on the island of Formosa, notes of taxonomic importance are presented herewith. Two species (in the genera *Sibbaldia* and *Spiraea*) and one variety are described as new, six new combinations are made, six names are newly reduced to synonymy, and other critical notes are presented. The genus *Rubus* has not been included but will be dealt with in a special treatment.

The specimens cited belong to the Herbarium of the National Taiwan University, Formosa, (indicated by NTU) and the U. S. National Herbarium (US). In the former case, only selected specimens are cited for each species.

Duchesnea Smith

Duchesnea indica (Andr.) Focke in Engl. & Prantl, Nat. Pflanzenfam. III. **3**: 33. 1888.

Duchesnea formosana Odashima in Journ. Soc. Trop. Agr. **7**: 79. 1935. *Syn. nov.*

Widely distributed from western to eastern and southern Asia. Common in Formosa.

Formosa: Taihoku, *T. Tanaka 1715* (US); Sendyosan, Taihoku, *T. Suzuki 5123* (NTU); Wantan, Sinten-syo, Bunzan-gun, Taihoku-syu, *H. Simizu 3317* (NTU).

Odashima established *D. formosana* on the ground that it is distinct from *D. indica* in the smaller stature, thinner leaves, and light red or whitish receptacle. One of his cited collections, *Tanaka 1715*, is now available. This and other Formosan specimens do not bear out the

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differences mentioned by Odashima. It seems that he separated plants that grow in a more shady environment. In this exceedingly variable species, it will be difficult and almost futile to distinguish local aggregates.

ERIOBOTRYA Lindley

Eriobotrya deflexa (Hemsley) Nakai f. **koshunensis** (Kanehira & Sasaki) comb. nov.

Eriobotrya deflexa var. *koshunensis* Kanehira & Sasaki in Sasaki, Cat. Govern. Herb. [Formosa] 246. 1930; Kanehira, Formos. Trees rev. ed. 261. *f. 206.* 1936.
Photinia buisanensis Hay. Icon. Pl. Formos. **3:** 100. 1913, p. p. (excl. typ.).
Eriobotrya deflexa f. *buisanensis* Nakai in Bot. Mag. Tokyo **30:** 18. 1916, p. p. (excl. typ.).
Eriobotrya buisanensis Kanehira, loc. cit. ed. 2. 218. 1918; Nakai in Journ. Arnold Arb. **5:** 70. 1924, p. p.

In thickets at low altitudes, Koshun peninsula.

Formosa: Kuraru, Koshun, *R. Kanehira 11710*, June 1917 (US, photo of type, *E. deflexa* var. *koshunensis* Kanehira & Sasaki).

Eriobotrya deflexa, a Formosan endemic, has three forms: f. *deflexa*, characterized by oblong-ovate to elliptic leaves, about 13–25 cm. long and 4.5–5.5 cm. broad; f. *buisanensis* Nakai, with oblong-lanceolate leaves, 9–14 cm. long and 1.5–2.5 cm. broad, and f. *koshunensis*, with obovate-oblong leaves, 7–14 cm. long, and 3–6 cm. broad.

PHOTINIA Lindley

PHOTINIA BEAUVERDIANA Schneider var. NOTABILIS Rehder & Wilson in Sarg. Pl. Wils. **1:** 188. 1912.

Pourthiaea beauverdiana var. *notabilis* Hatusima in Bull. Exp. For. Kyushu Univ. **3:** 99. 1933; Kanehira, Formos. Trees rev. ed. 267. *f. 213.* 1936.
Pourthiaea benthamiana Nakai in Bot. Mag. Tokyo **30:** 24. 1916, p. p.
Photinia fauriei Card. in Not. Syst. Lecomte **3:** 376. 1918. *Syn. nov.*
Photinia villosa Decaisne var. *sinica* sensu Sasaki, Cat. Govern. Herb. [Formosa]. 249. 1930, non Rehd. & Wils.

Southern China. Formosa, in forests at altitudes of about 1,000 meters, central and northern parts.

Formosa: Sinsuiei, Daibu-sicyo, *H. Simizu 3651* (NTU); Keelung, *E. H. Wilson 10217* (US).

The binomial *Photinia fauriei* Card. has been neglected by all Japanese botanists. No type material is at hand, but on the basis of the description it is apparently referable here.

PHOTINIA LUCIDA (Decaisne) Schneider, Ill. Handb. Laubholz. *1*: 710. 1906.

Pourthiaea lucida Decaisne in Nouv. Arch. Mus. Paris **10:** 148. 1874.
Photinia taiwanensis Hay. in Journ. Coll. Sci. Tokyo **30**(1): 104. 1911 (Mat. Fl. Formos.), Icon. Pl. Formosa. **1:** 247. *pl. 31.* 1911; Kanehira, Formos. Trees rev. ed. 266. *f. 212.* 1936.
Pourthiaea benthamiana Nakai in Bot. Mag. Tokyo **30:** 24. 1916, p. p.

Endemic to Formosa, common in thickets at low altitudes throughout the island.

Formosa: Matuyama, Taihoku-syu, *G. Masamune 2588* (NTU); Wantan, Taihoku-syu, *H. Shimizu 2066* (NTU); Sinten, Taihoku-syu, *K. Odashima 13606* (US); Sirin, Taihoku-syu, *K. Odashima 17780* (US).

Nakai interpreted the Formosan plant in question as composed of two species, one of them including the type of *P. taiwanensis* Hay. as well as specimens from Koshun, southern Formosa, and those later referred by Hayata to the Chinese *P. benthamiana* Hance. The other plants from Urai, Pachina, and Pikoh studied by Hayata were referred by Nakai to *Pourthiaea lucida* Decaisne. Nakai interpreted the former as having mature leaves villose beneath and the latter having mature leaves nearly glabrous. According to available material, the pubescent-leaved plant is *Photinia beauverdiana* var. *notabilis*, discussed above. The more glabrous leaved plant is evidently the one typified by Decaisne by "Oldham 99" and by Hayata by "Makino, Nov. 1896." This is *Photinia lucida*, the species with much longer fruiting pedicels.

PHOTINIA PARVIFOLIA (Pritz.) Schneider, Ill. Handb. Laubholz. **1**: 711. *f. 3920–0′*. 1906.

Pourthiaea parvifolia Pritzl in Bot. Jahrb. **29**: 389. 1900.
Pourthiaea kankaoensis Hatusima in Bull. Exp. For. Kyushu Univ. **3**: 99. 1933; Kanehira, Formos. Trees rev. ed. 267. *f. 214*. 1936. *Syn. nov.*

Southern China. Formosa, widely distributed at medium altitudes throughout the island.

Formosa: Hitiseigun, Daiton-hira, Taihoku-syu, *R. Nakamuda 4794* (NTU).

From the original description and Kanehira's interpretation, *P. kankaoensis* is apparently conspecific with *Photinia parvifolia*, a species common to and widely distributed in southern China.

PHOTINIA LASIOPETALA Hay. Icon. Pl. Formos. *6*: 17. *f. 1*. 1916; Kanehira, Formos. Trees rev. ed. 265. *f. 210*. 1936.

Formosa, known from the type only, Mushan, Baikei, *B. Hayata*, April, 1916 (US, photo).

This is a doubtful species needing further study. It is apparently very near *Photinia serrulata* Lindl., differing only in the pubescent-clawed petals.

PHOTINIA SERRULATA Lindl.

In this species three forms can be recognized in Formosa.

PHOTINIA SERRULATA Lindl. f. SERRULATA.

Photinia serrulata Lindl. in Trans. Linn. Soc. **13**: 103. 1821; Hay. in Journ. Coll. Sci. Tokyo **30**(1): 104. 1911 (Mat. Fl. Formos.), Icon. Pl. Formos. **1**: 247. 1911, **5**: 69. *f. 12*. 1915; Kanehira, Formos. Trees rev. ed. 265. *f. 312*. 1936.

Central and southern China to the Philippines. Formosa, in forests at 1,500–2,500 meters in the central part of the island and at about 300 meters around Kwarenko on the east coast.

Formosa: Arisan, *E. H. Wilson 9754* (US).

Photinia serrulata Lindl. f. **ardisifolia** (Hay.) comb. nov.

Photinia ardisifolia Hay. Icon. Pl. Formos. **5:** 65. 1915, **9:** 39. 1920; Kanehira, Formos. Trees rev. ed. 263. *f. 208.* 1936.

Endemic to the east coast, known from the type only, Manchosya, Taito, *G. Nakahara 22366* (US, photo).

This is manifestly of the same species as *Photinia serrulata* Lindl. and may represent a local form different only in the shape of the leaves.

Photinia serrulata Lindl. f. **daphniphylloides** (Hay.) comb. nov.

Photinia daphniphylloides Hay. Icon. Pl. Formos. **7:** 30. 1918; Kanehira, Formos. Trees rev. ed. 263. *f. 209.* 1936.
Photinia serrulata var. *aculeata* Lawrence in Gentes Herb. **8:** 80. 1949. *Syn. nov.*

Formosa: Between Shingio and Batakan, Kwarenko, *S. Sasaki 11811* (US, photo of isotype, *P. daphniphylloides* Hay.); Seisui, Kwarenko, *E. H. Wilson 11061* (US, isotype of *P. serrulata* var. *aculeata* Lawrence); Suiroku, Taroko, Kwarenko-syu, *S. Suzuki 8726* (NTU).

This form is apparently a local one confined to the vicinity of Kwarenko, on the east coast. It differs from the typical form of the species only in the broader leaves. The type of Lawrence's variety has serrations that are not sharp but are similar to those of most other specimens. Hayata's type is apparently from a collection with nearly entire leaves. The leaf-margins appear to vary considerably in this form as well as in the typical form of the species and apparently the shape of the leaf is a more consistent character in differentiating the forms.

To summarize the genus *Photinia*, a key to the Formosan species, varieties, and forms is given below:

A. Leaves deciduous; flowers in corymbs or cymes with conspicuous warty axes (Sect. *Pourthiaea*).
  B. Leaves larger, 6–11 cm. long.
    C. Leaves chartaceous, villose-pubescent beneath; fruiting pedicels hardly to 1 cm. long.... *P. beauverdiana* var. *notabilis*
    CC. Leaves thinly chartaceous, nearly glabrous beneath; fruiting pedicels 2–3 cm. long..... *P. lucida*
  BB. Leaves smaller, 3–4 cm. long..... *P. parvifolia*
AA. Leaves persistant; inflorescence corymbose-paniculate, not warty. (Sect. *Euphotinia*).
  B. Petals clawed and villose at base..... *P. lasiopetala*
  BB. Petals not clawed and not villose at base.
    C. Leaves narrower, less than 4 cm. in width.
      D. Leaves obovate to oblong, 9–15 cm. long, 2.5–4.5 cm. broad, the base acute to rounded.. *P. serrulata f. serrulata*
      DD. Leaves ovate-lanceolate, 7.5–10 cm. long, 2–2.3 cm. broad, attenuate at base..... *P. serrulata f. ardisifolia*
    CC. Leaves broader, elliptic to obovate-oblong, 8–14 cm. long, 4–5.7 cm. broad, cuneate to rounded at base..... *P. serrulata f. aculeata*

POTENTILLA Linnaeus

Potentilla leuconota Don var. **tugitakensis** (Masamune) comb. nov.

Potentilla tugitakensis Masamune in Journ. Soc. Trop. Agr. **4:** 77. 1932.

Endemic, high mountains at about 3,500 meters.

Formosa: Bunakkei, Nankotaisan, Ratogun, Taihoku-syu, *T. Suzuki, N. Fukuyama, & H. Shimada 17374* (NTU).

This variety is similar to the other variety in Formosa, *P. leuconota* var. *morrisonicola* Hay., but with much larger flowers.

Prunus Linnaeus

Prunus macrophylla Sieb. & Zucc. Fl. Jap. Fam. Nat. 14. 1843; Kanehira, Formos. Trees rev. ed. 270. *f. 218.* 1936.

Prunus kanehirai Hay. ex Hisauchi in Journ. Jap. Bot. **12:** 54. 1936. *Syn. nov.*

Indo-China, China, Liukiu, to southern Japan. Formosa, in primary forests at medium altitudes of about 600 meters.

Formosa: Taihoku, *Kei-Rai Lin,* Jan. 31, 1939 (NTU); Taihoku, Bunzan-gun, *T. Suzuki 17077* (NTU).

The Formosan plant is very close to the typical form in Japan and better considered conspecific with it than distinct as suggested by Hisauchi. Plants from Hainan, Indo-China, and southwestern China show much wider deviation from the Japanese plants than those of Formosa, but apparently they represent only local forms of a widely distributed species.

Raphiolepis Lindley

Raphiolepis indica Lindl.

There are two elements of this species in Formosa, var. *tashiroi* in the central and northern parts with more hairy inflorescence, and var. *hiranensis* in the southern part, with few-flowered, nearly glabrous inflorescence.

Raphiolepis indica Lindl. var. tashiroi Hay. in Matsum. & Hay. in Journ. Coll. Sci. Tokyo **22:** 129. 1906 (Enum. Pl. Formos.), p. p.; Kanehira, Formos. Trees rev. ed. 277. *f. 227.* 1936.

Raphiolepis indica sensu Hay. Icon. Pl. Formos. **1:** 248. 1911, non Lindl.

Formosa: Lake Candidus, *E. H. Wilson 9970* (US), *11179* (US); Bot. Garden, Taiwan Univ., *Kei-Rai Lin,* April 8, 1940 (NTU), Nov. 17, 1940 (NTU).

Raphiolepis indica Lindl. var **hiiranensis** (Kanehira) comb. nov.

Raphiolepis hiiranensis Kanehira, Formos. Trees rev. ed. 276. *f. 226.* 1936.

Formosa: South Cape, *A. Henry 643A* (US).

Rosa Linnaeus

Rosa luciae Franch. & Roch. var. **rosea** var. nov.

A typo speciei differt floribus roseis parvis 1.5 cm. diametro.

Endemic to Formosa, along sea shore.

Formosa: On limestone, Seisui, prov. Kwarenko, *E. H. Wilson 11067,* Nov. 2, 1918 (US, 1053094, type).

This particular specimen was identified by Herring in 1948 as a variety of *R. cymosa*. Although the plant has the general appearance of *R. cymosa*, it is readily separated from the latter by its adnate instead of free stipules. It clearly belongs to *R. luciae*, which in Formosa occurs along the coastal regions. This particular plant, growing on limestone cliffs of the steep coast of the east, differs from those of other places in the smaller pink flowers.

SIBBALDIA Linnaeus

Sibbaldia taiwanensis sp. nov.

Sibbaldia procumbens sensu Hay. in Journ. Coll. Sci. Tokyo **25**(19): 84. 1908 (Fl. Mont. Formos.), Icon. Pl. Formos. **1**: 238. 1911; Koidz. in Journ. Coll. Sci. Tokyo **34**(2): 193. 1913, p. p.; Sasaki in Cat. Govern. Herb. [Formos.] 261. 1930; Kudo & Masamune in Ann. Rep. Taihoku Bot. Gard. **2**: 113. 1932; Hosokawa in Masamune, Short Fl. Formos. 91. 1936; non L.

Herba perennis, dense caespitosa, rhizomate lignoso; caulibus ad 8 cm. altis; foliis semper radicantibus; foliolis 3, obovatis, ad 10 mm. longis et 7 mm. latis, apice truncatis, 3-fidis, basi cuneatis, sessilibus, utrinque dense villoso-hirsutis, venis obscuris; petiolis ad 2.5 cm. longis, dense hirsutis; stipulis magnis, membranaceis; inflorescentiis cymosis, paucifloris, dense villoso-hirsutis; pedicellis circiter 5 mm. longis; calyce 5 mm. longo, lobis triangulari-lanceolatis, in fructu erectis; bracteis linearibus, petalis flavis, obovatis, calycem excedentibus; staminibus 5–10, parvis; fructibus ovoideis, glabris, obtusis, receptaculo plano, pubescente.

Endemic, high mountain peaks in the central part of the island.

Formosa: Mt. Tugitaka, *S. Suzuki 5379*, July 8, 1939 (NTU, type).

This species is quite different from *S. procumbens* but more closely related to *S. parviflora* Willd. *Sibbaldia procumbens* L. is a species of Europe, distributed in Russia, Switzerland, France, Scotland, Spain, and the Alps. As pointed out by Chatterjee (Notes Bot. Gard. Edinb. **19**: 325. 1938), this species was wrongly quoted by Hooker in Fl. Brit. Ind. as synonymous with *S. parviflora* Willd., now recognized as distinct. *Sibbaldia parviflora* occurs in northern Asia, western Tibet, alpine Himalayas, and Yunnan, as well as in North America. Other related species are found in the eastern Himalayan region. I have seen no specimens of this genus from Japan, but the Formosan plant, compared with plants from the Himalayas, western China, and northern Asia, is more densely tufted, much more densely hirsute on its leaves and inflorescences, and with the leaflets narrower at base and more nearly sessile. The Formosan plant may also be considered as a variety of *S. parviflora* if a wider concept of the species is preferred.

SPIRAEA Linnaeus

Spiraea prunifolia Sieb. & Zucc. var. **pseudoprunifolia** (Hay.) comb. nov.

Spiraea pseudoprunifolia Hay. ex Nakai in Bot. Mag. Tokyo **29**: 75. 1915, in adnot., Gen. Ind. Fl. Formos. 43. 1916.

Spiraea prunifolia sensu Matsum. & Hay. in Journ. Coll. Sci. Tokyo **22**: 119. *pl. 12*. 1906 (Enum. Pl. Formos.); Koidz. in Journ. Coll. Sci. Tokyo **34**(2): 11. 1913 (as *α typica*); Rehder in Sarg. Pl. Wils. **1**: 438. 1913, p p.

Spiraea prunifolia Sieb. & Zucc. var. *typica* Schneider, Illus. Handb. Laubholz. **1:** 450. 1905, p. p.; Kudo & Masamune in Ann Rep. Taihoku Bot. Gard. **2:** 123. 1932.

Eastern China (Chekiang, Anhwei), and Formosa.

Formosa: Taka, *Masamune 3811* (NTU); Musha, Nanto, *Wilson 10033* (US).

This Formosan plant is either treated as a straight synonym of *S. prunifolia* Sieb. & Zucc. of Japan, Korea, and China, as by Kudo & Masamune (l.c.) and Hosokawa (in Masamune, Short. Fl. Formos. 92. 1936), or as a distinct species, as by Nakai (l.c.) and Hatusima (l.c.). The plant from Formosa as well as from eastern China is indeed close to *S. prunifolia*, and the differences, in the thicker more pubescent leaves and smaller flowers, are slight. It is better treated as a variety of this species.

Spiraea hayatana sp. nov.

Frutex parvus, ad 1.5 m. altus; ramulis gracilibus, fusco-ferrugineis, ramulis novellis puberulis; foliis chartaceis, breviter petiolatis, ovato-oblongis, 2–3.5 cm. longis, 1–1.8 cm. latis, apice acutis vel acuminatis, basi acutis, margine plus minusve distincte duplicato-serratis, utrinque glabris, supra viridibus, subtus pallidis, costa venisque supra leviter impressis, subtus distinctis, elevatis, venis secundariis utrnisecus 4 vel 5, valde adscendentibus, venulis reticulatis, plus minusve parallelis, subtus valde elevatis; petiolis 1–2 mm. longis, alatis, pubescentibus; inflorescentiis terminalibus corymbosis, ad 5 cm. longis et 5.5 cm. latis, minute pubescentibus; floribus circiter 4 mm. diametro; bracteis minutis, subulatis, haud 1 mm. longis; pedicellis gracilibus, 3–4 mm. longis, in fructu ad 6–8 mm. longis; calyce rotato-campanulato, circiter 1.5 mm. longo, extus pubsecente, intus glabro, 5-lobato, lobis triangularibus, 0.5 mm. longis; petalis obovatis, 2 mm. longis, apice rotundatis vel subemarginatis; staminibus circiter 20, longe exertis, filamentis circiter 2 mm. longis, antheris minutis; carpellis maturis brunneis, circiter 2 mm. longis, glabris, leviter rostratis, erectis.

Formosa: Mt. Nankotaizan, *S. Suzuki*, July 1922 (NTU, type, flower); Mt. Arisan to Mt. Morrison, prov. Kagi, alt. 3,000–3,500 meters, *E. H. Wilson 10944* (US, fruit).

Stranvaesia Lindley

Stranvaesia niitakayamensis (Hay.) Hay. Icon. Pl. Formos. **8:** 33. 1919; Kanehira, Formos. Trees rev. ed. 286. *f. 243.* 1936.

Photinia niitakayamensis Hay. in Journ. Coll. Sci. Tokyo **30**(1): 103. 1911, Icon. Pl. Formos. **1:** 246. 1911.

Stranvaesia davidiana Decaisne var. *salicifolia* sensu Sasaki, List Pl. Formos. 122. 1928, non Rehder.

Photinia undulata Card. var. *formosana* Card. in Not. Syst. Lecomte **3:** 372. 1918. *Syn. nov.*

Endemic to Formosa, in forests at high altitudes of over 2,000–3,300 meters in the central ranges.

Formosa: Arisan, *Y. Yamamoto & T. Nakamura 4096* (NTU),

E. H. Wilson 9724 (US), *R. Kanehira & S. Sasaki 21707* (US); Mt. Morrison, *H. H. Bartlett*, Oct. 9, 1926 (US).

The name *Photinia undulata* Card. var. *formosana* Card., based on *Faurie 77* and *1371* from Arisan, was overlooked by all Japanese botanists. Although the description is very brief, it is undoubtedly referable to the present species, as Cardot compared his plant with *Photinia niitakayamensis* Hay. He called his *Photinia undulata* a new combination, but failed to quote the basonym. Doubtless he meant *Stranvaesia undulata* Decaisne, as indicated in Index Kewensis Suppl. 7, a name which is now generally treated as *Stranvaesia davidiana* Decaisne var. *undulata* (Decaisne) Rehder & Wilson.

Masamune (in Kudo & Masamune in Ann. Rep. Taihoku Bot. Gard. **2**: 127. 1932) listed *Stranvaesia impressivena* (Hay.) Masamune, a new combination based on *Photinia impressivena* Hay., as occurring in Formosa. He gave *S. davidiana* Decaisne var. *salicifolia* sensu Sasaki (non Rehder) in synonymy. However, *Photinia impressivena* Hay., a little known species, is based on a collection from Fukien ("Fokien: Mt. Kozan, leg. S. Nagasawa, Nov. 1909, [Fr.]"), which Hayata compared with *Photinia amphidoxa* Rehder & Wilson. Whatever the identity of this plant may be, it should be removed from the list of Formosan plants.

Phosphate Absorption by Georgia Grass (Paspalum plicatulum Michx.)[1]

F. L. Wynd[2]

INTRODUCTION

Nueces fine sand is a very widely distributed soil type in the coastal area of southern Texas. Its entire area, with minor exceptions, is devoted to cattle grazing because its comparatively low fertility and the arid climate of the region render other agricultural uses unprofitable. Unfortunately, the amount of available phosphorus in Neuces fine sand is so low that cattle grazed continuously in the area suffer from acute phosphorus deficiency. An adequate pasture management program therefore demands phosphate fertilization.

The expense of fertilizing such a large area makes it important to know the comparative availabilities of rock phosphate and the more expensive superphosphate under the specific environment imposed by the soil type and the climatic conditions.

EXPERIMENTAL MATERIALS AND METHODS

Experimental plots were established on the Armstrong Ranch in Kenedy County, Texas, by Mr. W. J. McBride, Agent in Animal Husbandry of the United States Department of Agriculture, Bureau of Animal Industry. Rock phosphate, and superphosphate (0–20–0) were added to adjacent plots at the rate of 200 pounds per acre. The unfertilized area surrounding the fertilized plots was used as the control area. The fertilizer was added evenly to the surface. The original native stand of Georgia grass, *Paspalum plicatulum* Michx., was not disturbed. Samples of this species were collected by hand on June 5, 1948, of the following season, dried, and forwarded to the Plant Physiology Laboratory of the Department of Botany and Plant Pathology, Michigan State College, for chemical analysis.

The percentages of phosphorus in the herbage were determined by wet ashing of one-gram samples with a mixture of perchloric and nitric acids. The residue was diluted with water, filtered to remove silica, and brought to a standard volume. Phosphorus was determined in suitable aliquots of the filtered solution by the conventional procedure recommended by the Association of Official Agricultural Chemists (1).

Total acid-hydrolyzable carbohydrate was determined by refluxing one-gram samples of the finely ground dry material in 20 percent hydrochloric acid for three hours. After refluxing, the solution was neutralized, clarified with neutral lead acetate, freed from excess lead

[1]The expenses of this study were borne by a grant-in-aid contributed by the King Ranch, Texas.

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with potassium oxalate, filtered, and brought to a volume of 500 milliliters. Reducing sugar was determined in aliquots of three milliliters by the micro method described by Heinze and Murneek (2).

The total nitrogen content of the grass was determined by the modified Kjeldahl procedure recommended by the Association of Official Agricultural Chemists (1).

EXPERIMENTAL RESULTS

The data in Table 1 show that the dry material of unfertilized *Paspalum plicatulum* contained 0.097 percent phosphorus. The application of rock phosphate at the rate of 200 pounds per acre did not increase the percentage of phosphorus in the herbage. In fact, the phosphorus content was only 89 percent of the control value. It is not likely that the application of rock phosphate actually lessened the absorption of phosphorus. The observed lower value was due,

TABLE 1. *Phosphorus content of Paspalum plicatulum Michx., expressed as percentages of the dry material.*

SAMPLE NO.	TREATMENT	PERCENT PHOSPHORUS		
		Det. 1	Det. 2	Ave.
T-851	Control	0.098	0.096	0.097
T-852	200 lbs. Rock P	0.086	0.086	0.086
T-853	200 lbs. Super P	0.174	0.166	0.172

more likely, to a slightly more mature stage of growth of the grass. The application of superphosphate (0–20–0) at the rate of 200 pounds per acre significantly increased the percentage of phosphorus in the herbage. The data in Table 1 show that the value for the fertilized grass was equal to 177 percent of that obtained for the unfertilized grass. It is apparent that rock phosphate was ineffective in increasing the percentage of phosphate in the plants, while the superphosphate was markedly effective.

The unfertilized plants of *Paspalum plicatulum* Michx. contained 1.13 percent nitrogen, or approximately 7.07 percent protein. The data in Table 2 show that the herbage from the plot treated with rock phosphate contained 0.97 percent nitrogen or approximately 6.07 percent protein. This lower value was due probably to the slightly greater maturity of the plants as mentioned above. The addition of superphosphate increased slightly the percentage of nitrogen in the herbage. The data show that the percentage was increased to about 105 percent of the control value.

The percentages of total carbohydrate in the herbage was increased markedly by the applications of both rock phosphate and superphosphate. The data in Table 3 show that the rock phosphate increased the carbohydrate content to 127 percent of the control value, although

it should be borne in mind that at least part of this increase was due to the greater maturity of the sample as already described. The addition of superphosphate to the soil increased the percentage of carbohydrate to 121 percent of the control value.

DISCUSSION

The data presented indicate, in spite of their brevity, that fertilization of Nueces fine sand with 200 pounds of superphosphate (0–20–0) markedly increased the nutritive value of Georgia grass, *Paspalum plicatulum* Michx. Not only was the percentage of phosphorus in the

TABLE 2. *Nitrogen content of Paspalum plicatulum Michx., expressed as percentages of the dry material.*

SAMPLE NO.	TREATMENT	TOTAL NITROGEN			PROTEIN, N x 6.25		
		Det. 1	Det. 2	Ave.	Det. 1	Det. 2	Ave.
T-851	Control.....	1.10	1.16	1.13	6.88	7.25	7.07
T-852	200 lbs. Rock P...	0.96	0.98	0.97	6.00	6.13	6.07
T-853	200 lbs. Super P...	1.18	1.20	1.19	7.38	7.50	7.44

TABLE 3. *Total carbohydrate content of Paspalum plicatulum Michx., expressed as percentages of the dry material.*

SAMPLE NO.	TREATMENT	CARBOHYDRATE		
		Det. 1	Det. 2	Ave.
T-851	Control.....	23.4	23.7	23.6
T-852	200 lbs. Rock P.....	31.1	29.8	30.0
T-853	200 lbs. Super P.....	28.2	28.7	28.5

herbage increased, but the percentage of nitrogen, and also of total carbohydrates, was augmented as well. The increase in the carbohydrate content was especially apparent.

The application of 200 pounds of finely ground rock phosphate did not effect the concentration of phosphorus or of nitrogen in the herbage. The carbohydrate content, on the other hand, appeared to be considerably augmented. If we assume that rock phosphate is only slightly available to the grass under the conditions of the experiment, it follows that the percentage of this substance in the grass need not necessarily be increased. It is likely, however, that even a slight availability might influence the total growth of the grass. Unfortunately, accurate total yield data are almost impossible to obtain under the conditions imposed on experiments on the open range. The

significantly greater concentration of carbohydrate in the grass fertilized with rock phosphate suggests that this fertilizer did exert some favorable influence, even though the actual percentage of phosphorus in the grass was not increased.

It has been observed frequently that cattle prefer to graze from areas fertilized with phosphate. The animals quickly locate the experimentally fertilized areas on the open range, and graze to the exact boundary of the fertilized soil. It is very probable that the preference which the animals show for phosphate-fertilized pasture is based on the greater carbohydrate content of the herbage.

SUMMARY AND CONCLUSIONS

1. Rock phosphate and superphosphate (0–20–0) were added at the rate of 200 pounds per acre to adjacent plots of Nueces fine sand in Kenedy County, Texas. The native herbage was almost a pure stand of Georgia grass, *Paspalum plicatulum* Michx. The herbage was sampled in June of the following season, and the percentages of phosphorus, nitrogen, and carbohydrate were determined.

2. Rock phosphate did not effect the percentages of phosphorus or of nitrogen in the herbage. However, the carbohydrate content was increased.

3. Superphosphate greatly increased the concentration of phosphorus and carbohydrate in the herbage. The nitrogen content was increased only slightly.

4. Rock phosphate was not a satisfactory source of phosphate for the phosphorus-deficient Nueces fine sand of the coastal area of southern Texas. Superphosphate, on the other hand, was a satisfactory source of phosphorus under the conditions imposed by soil type and climate of the area.

5. Cattle prefer to graze the phosphate-fertilized pastures, probably because of the higher carbohydrate content induced by this fertilizer.

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New genera, species, etc., are indicated by *italics*.